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SHIPMO7: AN UPDATED STRIP THEORY PROGRAM FOR PREDICTING SHIP MOTIONS AND SEA LOADS IN WAVES

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Abstract

SHIPMO7 is an updated strip theory program for computing ship motions and sea loads in regular and irregular seas. SHIPMO7 includes appendage forces and viscous forces when evaluating motions and sea loads in the lateral plane. The revised program also introduces a boundary element method which eliminates irregular frequencies from computed hydrodynamic coefficients. The SHIPMO input format has been revised to improve consistency and clarity. The revised output includes improvements to aid checking of input data for ship appendages. In addition to computing ship motions and sea loads, SHIPMO7 also gives derived responses, including local accelerations, slamming, deck wetness, motion-induced interruptions, and added resistance in waves.

Résumé

Le SHIPMO7 est un programme actualisé de calcul des mouvements des navires et des forces marines dans les mers régulières et irrégulières. Il prend en compte les forces des appendices et les forces de viscosité pour évaluer les mouvements et les forces marines dans le plan latéral. Le programme révisé introduit aussi une méthode des éléments limites qui élimine les fréquences irrégulières des coefficients hydrodynamiques calculés. On a révisé le format des entrées SHIPMO pour le rendre plus cohérent et plus clair. On a aussi révisé les sorties pour faciliter la vérification des données d'entrée des appendices des navires. En plus de calculer les mouvements des navires et des forces marines, SHIPMO7 donne des réponses dérivées dont les accélérations locales, les mouvements des navires et les forces marines, le talonnement, le mouillage des ponts, les interruptions induites par les mouvements et l'augmentation de la résistance dans les vagues.

DREA TM/96/243

SHIPMO7: An Updated Strip Theory Program for Predicting Ship Motions and Sea Loads in Waves

by

Kevin McTaggart

EXECUTIVE SUMMARY

Introduction

Predictions of ship motions and sea loads are of fundamental importance in ship design and maintenance. Although advanced techniques such as three-dimensional panel codes and time domain programs have been under development for many years, strip theory is still the most commonly used method for predicting ship motions and sea loads because of its efficiency and robustness. This manual documents SHIPMO7, the latest version of DREA's strip theory program.

Principal Results

SHIPMO7 introduces several improvements over previous versions of the program. A new boundary element method for computing sectional hydrodynamic coefficients eliminates problems with irregular frequencies. The revised program computes sea loads, including appendage forces and viscous forces, which are significant for lateral plane loads. Special attention is given to the consistent treatment of forces acting on the ship during both motion and load predictions. The program also has revised input and output, which has been designed to assist the user to check the consistency of program input. Initial validation studies using experimental data for frigate models have indicated excellent agreement for motion predictions and good agreement for sea load predictions.

Significance of Results

SHIPMO7 is an efficient and robust program for predicting motions and sea loads of slender ships ($L/B > 4$) operating in moderate sea conditions (up to Sea State 7 for naval frigates). The general reliability of the code makes it suitable for routine engineering application. For cases beyond the limits of strip theory, such as low L/B vessels and extreme sea states, SHIPMO can provide reliable initial estimates of motions and loads that can be supplemented by more complex methods such as time domain codes.

Future Plans

SHIPMO7 will become DND's standard program for predicting ship motions and sea loads in waves. An industrial partner will likely develop a graphical user interface and market the program under license. DREA will update its ship operability code SHIPOP to interface with SHIPMO7. In support of structural design and maintenance, DREA plans to interface SHIPMO7 with wave statistical data to estimate structural design loads.

Contents

Notation

A	sectional area at midships
$A(P_i)$	spectral normalization factor
A_{44}	roll added moment of inertia
A_{wp}	waterplane area
a	wave amplitude
B	beam
$BFREQTANK$	break frequency for U-tube stabilizer tank
C_B	block coefficient
C_P	prismatic coefficient
C_{VP}	vertical prismatic coefficient
CG	centre of gravity
$DAMPFIN$	damping coefficient of stabilizer fin control system
$DAMPRUD$	damping coefficient of rudder control system
$DEADR$	slamming deadrise angle
$DRAFTMID$	draft of baseline at midships
F_{max}	maximum slamming force per unit length
$FFACT$	slamming form factor
$FREQFIN$	natural frequency of stabilizer fin control system
$FREQRUD$	natural frequency of rudder control system
$G(\theta)$	directional spreading function
$\overline{GM}$	metacentric height
g	gravitational acceleration
H_s	significant wave height
h	steady wave elevation or height above deck of CG of person
HCG	height of CG above waterline
I_{44}	roll moment of inertia
K_{44}	roll stiffness
$\overline{KG}$	height of CG above baseline

k	wavenumber
k_r	constant for computing sectional gyradii
L	ship length between perpendiculars
LCG	longitudinal centre of gravity
$LCGFP$	distance from forward perpendicular to LCG
l_i	length of section i
$M_i(\nu)$	directional spreading function of bimodal spectral component i
m_i	mass of section i or i'th moment of spectrum
P_i	spectral directional spreading parameter
p_{max}	maximum slamming pressure
$RAGNFIN$	stabilizer fin control roll acceleration gain
$RAGNRUD$	rudder control roll acceleration gain
$RESISTBTANK$	U-tube tank resistance coefficient above break frequency
$RESIST0TANK$	U-tube tank resistance coefficient at zero frequency
$RGNFIN$	stabilizer fin control roll gain
$RGNRUD$	rudder control roll gain
$ROLLNF$	ship roll natural frequency
$RVGNFIN$	stabilizer fin control roll velocity gain
$RVGNRUD$	rudder control roll velocity gain
r_{xx-i}	local roll gyradius of section i
$S(T), S(\omega)$	unidirectional wave spectral energy density
$SLFORM$	slamming form factor
$SLHEIGHT$	height limit above keel of slamming pressure
$SLWIDTH$	effective width of slamming pressure
s	uncorrected relative motion or half stance width of person on deck
s_c	corrected relative motion
T	draft or wave period
T_{C-max}	maximum characteristic wave period
T_{C-min}	minimum characteristic wave period
T_p	peak wave period

T_x	sectional draft
T_z	zero-crossing period of spectrum
T_1	period corresponding to energy averaged wave frequency
T_{-1}	energy averaged wave period
$TRIMST$	ship trim by stern (positive for bow up)
U	ship speed
V_r	relative vertical velocity
$WETROLLRG$	wet roll gyradius of ship
x, y, z	coordinate system
x_{mid}	x coordinate of midships
$YAGNRUD$	rudder control yaw acceleration gain
$YGNRUD$	rudder control yaw gain
$YVGNRUD$	rudder control yaw velocity gain
z_{bl}	z coordinate relative to baseline
z_{wl}	z coordinate relative to waterline
α^*	normalization factor for JONSWAP spectrum
β	stabilizer fin deflection angle
β_c	stabilizer fin command deflection angle
β_s	direction of wave relative to ship velocity; $\beta_s = 180^\circ$ for head seas
Γ	foil dihedral angle
$\Gamma(x)$	gamma function
γ	peak enhancement factor for JONSWAP spectrum
γ_s	wave spreading angle
δ	rudder deflection angle
δ_c	command rudder deflection angle
Δz	correction of z coordinate due to ship trim
ζ_i	significant wave height of directional wave spectrum component i
η_1, η_2, η_3	ship translational displacements (surge, sway, and heave)
η_4, η_5, η_6	ship angular displacements (roll, pitch, and yaw
θ	wave direction relative to principal wave direction

κ	exponent for JONSWAP spectrum
λ_i	spectral shape parameter of bimodal spectrum component i
λ_s	tank valve resistance coefficient
ν	compass bearing from which wave component is approaching
ν_{m-i}	mean compass direction (from) of bimodal spectrum component i
ρ	water density
σ	JONSWAP spectrum coefficient
χ	compass bearing of ship forward velocity
ω	wave frequency
ω_e	wave encounter frequency
ω_{e-o}	lowest wave encounter frequency for valid motion predictions
ω_p	peak wave frequency
ω_{p-i}	peak wave frequency of bimodal spectrum component i
ω_{-1}	frequency corresponding to energy averaged wave period
$\triangle$	ship mass displacement
∇	ship volume displacement

1 Introduction

This manual describes a new version of D REA's ship motion program SHIPMO [1, 2, 3, 4, 5, 6]. SHIPMO7 introduces major revisions to many aspects of SHIPMO, including capabilities, input and output format, and coding.

SHIPMO7 provides motion and load predictions using a frequency domain strip theory approach from Salvesen et al. [7]. For motions and loads in the lateral plane, appendage and viscous forces are significant and are computed using the methods of Schmitke [8], which have been updated to include Himeno's method [9] for eddy roll damping. SHIPMO7 gives motion and load predictions as amplitudes and phases for regular waves and as RMS values and zero-crossing periods for irregular seas, which can be modelled by a variety of wave spectra. The frequency of motion-induced interruptions [10, 11] in irregular seas can also be computed.

When using a frequency domain strip theory code such as SHIPMO, one must be aware of its limitations due to the assumptions of slenderness, low ship speed, and linearity. References 12 and 13 indicate that SHIPMO gives good motion predictions for $L/B > 4$. An extensive validation of ship motions and sea loads by Chow and McTaggart [14] suggests that SHIPMO will give valid results for moderate ship speeds ($Fn < 0.4$). Unpublished work at DREA indicates that the linearity assumption gives valid results for a naval frigate up to Sea State 7 .

The objective of this manual is to provide sufficient information for the user to apply SHIPMO intelligently without being overwhelmed by theoretical details. The manual provides guidance regarding the selection of appropriate input parameters and interpretation of results. Much of the theoretical background can be reviewed in the references if desired. If the user wishes to obtain useful background information on the theory and application of seakeeping codes such as SHIPMO, References 15 and 16 are among the best sources available.

2 Overview of Changes to SHIPMO

The new version of SHIPMO includes many changes to its capabilities, input format, and computational methods. These changes aim to enhance the scope, ease of use, and accuracy of the code.

2.1 Capabilities

The most significant new capability for SHIPMO7 is the prediction of sea loads. DND hopes to use reliability methods for structural design and maintenance; thus, structural finite element codes will require sea load predictions as input. Although SHIPMO2 [2] includes a sea loads capability, it was abandoned in subsequent versions of SHIPMO because of high memory requirements (relative to available computers at the time) and limited accuracy in load predictions from strip theory [17]. Sea loads arise from differences between hydrodynamic and inertial forces; thus, a small error in one of the contributing forces can cause a large error in the resulting sea loads. It was postulated that consistent treatment of forces for both motion and load computations could minimize resulting errors in sea loads. Consequently, it was decided to attempt to obtain successful sea load predictions using SHIPMO7. A correlation study by Chow and McTaggart [14] indicates that SHIPMO7 gives good sea loads predictions for both vertical and lateral modes. To assist the user in checking input mass distribution data, SHIPMO7 computes and outputs mass distribution parameters based on other user input, which can be checked with computed hydrostatic parameters for consistency of the ship displacement, longitudinal centre of gravity, and other inertial parameters. For lateral sea loads, SHIPMO7 includes all appendage and viscous forces that influence ship motions to ensure consistency between motion and load predictions.

SHIPMO7 introduces a capability for predicting added resistance in waves using the near-field method of Faltinsen et al. [18]. Reference 19 describes the implementation of this method into SHIPMO and gives validation results. SHIPMO7 can evaluate the effect of swell-up on relative motions using the method of Blok and Huisman [20], which replaces the empirical method previously used in SHIPMO.

2.2 Input Format

The input format for SHIPMO7 introduces significant changes relative to previous versions. When SHIPMO was previously updated, great care was given to ensuring that input files for older versions could run under the new version. Unfortunately, this compatibility prevented the input format from being modified to suit best the new program. More recently, SHIPMO users have indicated that it takes relatively little effort to update input files to a revised format for a new version of the code. SHIPMO7 introduces a new input format which is more logical and consistent than previous versions of the code. The new input format is in roughly the same sequence as previous versions, which should make conversion of older input files relatively easy.

SHIPMO7 replaces control integers with descriptive character strings to select program options. This revision simplifies preparation of input and improves readability of input files.

Like SHIPMO6, all vertical coordinates for SHIPMO7 are given relative to the ship baseline. The only major change to input coordinates is that a positive foil dihedral angle means that the tip of a foil is at a higher elevation than its root. Consequently, propeller shaft bracket arms typically have values of -100 to -150 degrees for outboard arms and -30 to -80 degrees for inboard arms. Stabilizing fins typically have values in the range of -20 to -70 degrees.

2.3 Computations

For predicting sectional hydrodynamic coefficients, a new boundary element method [21, 22] replaces the Frank Close-Fit method [23]. The new method eliminates irregular frequencies, which can cause large errors in sectional hydrodynamic coefficients and wave diffraction forces. As an alternative to the boundary element method, the conformal mapping method is still available in SHIPMO7.

For eddy roll damping, Himeno's method [9] replaces the method described by Schmitke [8]. Himeno's method is superior because the user only has to supply sectional dimensions and no longer has to provide an additional flag indicating the section type for eddy computations. In addition, Himeno's method seems to give more consistent results because it is a single unified theory.

3 Program Input

Appendix A gives a detailed specification of the SHIPMO7 input. This section elaborates on various aspects of the SHIPMO7 input for which the user may wish further guidance.

3.1 Dynamic Waterline and Swell-Up Correction at Forward Speed

Record (b) of the SHIPMO7 input has control variables SPEEDCOR and SWELLCOR to determine the dynamic waterline and swell-up correction at forward speed. The dynamic waterline modifies local drafts and freeboards at forward speed for deck wetness, slamming, and emergence calculations at seakeeping stations. The dynamic waterline does not affect sectional drafts used for computing sectional hydrodynamic coefficients. SHIPMO uses Shearer's method [24] as implemented in Reference 25 for predicting the dynamic waterline. A key assumption of Shearer's method is that sectional area changes gradually with length. When this assumption is valid for a given ship, the method will likely give good predictions. For a ship with a transom stern (e.g. a modern frigate), Shearer's method gives poor results at the stern; thus, variable SPEEDCOR should be set to NOSPEEDCOR for no speed correction, or to BOWSPEEDCOR for the computed dynamic waterline to be multiplied by a factor decreasing linearly from 1.0 at midships to 0.0 at the transom. Figure 1 shows the predicted dynamic waterline at 18 knots for the example frigate output of Appendix B.2 with SPEEDCOR set to BOWSPEEDCOR.

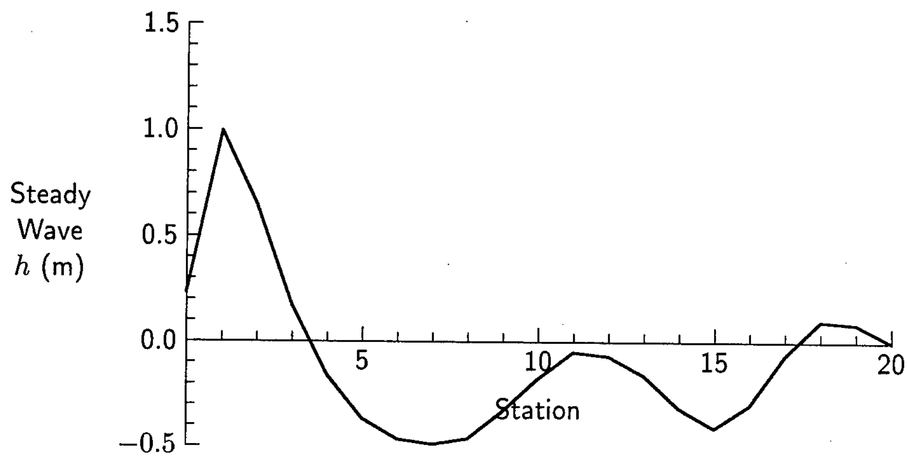


Figure 1: Dynamic Waterline at 18 knots for Example Frigate

The variable SWELLCOR determines whether Blok and Huisman's method [20] will be used to consider the influence on relative motion of swell-up due to ship forward speed. The swell-up correction affects relative motions, deck wetness, slamming, and emergence calculations at seakeeping stations at forward speed. The physical source of this phenomenon is that the ship relative motions cause changes in local drafts, which cause changes in the wave profile due to ship forward speed. For example, if relative motion causes bow emergence at forward speed, then the greater bow draft on submergence will typically increase the height of the steady bow wave, thus accentuating the relative motion. The corrected relative motion is computed as follows:

$$s_c(x,y,z,t) \quad = \quad s(x,y,z,t)\left(1 + \frac{\partial h(x,U)}{\partial T}\right) \tag{3.1}$$

where s_c is the corrected relative motion, x, y, and z are coordinates referenced to the ship centre of gravity (Figure 2), s is the uncorrected relative motion based on incident wave elevation and local vertical motion, h is the steady wave elevation, and T is ship draft. The swell-up correction factor $1+\partial h(x,U)/\partial T$ is typically greater than 1.0. SHIPMO uses Shearer's method to evaluate $h(x,U)$ at the design draft and at a second draft $T+\Delta T$ to obtain $\partial h(x,U)/\partial T$. Due to the limitations of Shearer's method discussed in the previous paragraph, SWELLCOR should be set to NOSWELLCOR or BOWSWELLCOR for transom stern ships. SHIPMO sets a range limit of 0.0-2.0 for the swell-up correction factor $1+\partial h(x,U)/\partial T$. Figure 3 shows the predicted swell-up correction factor at 18 knots for the example frigate output of Appendix B.2 with SWELLCOR set to BOWSWELLCOR.

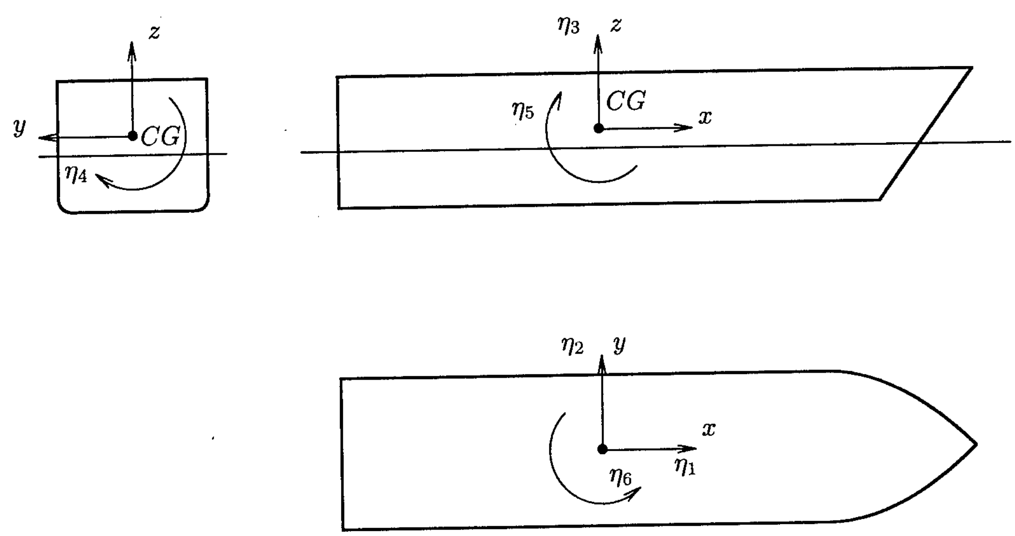


Figure 2: Ship Coordinate System for Motion Computations

3.2 Wave Frequencies

Input Record (d) gives minimum, maximum, and increment values for wave frequencies. For a ship in irregular seas, the minimum and maximum frequencies should be set such to encompass energy of the input wave spectrum. The SHIPMO7 output gives wave energies and computed significant wave height for the input wave frequency range, which can be checked to ensure that the wave frequencies encompass the wave spectral energy. For a typical ocean spectrum, wave energies will lie in the range of 0.2-2.0 rad/s.

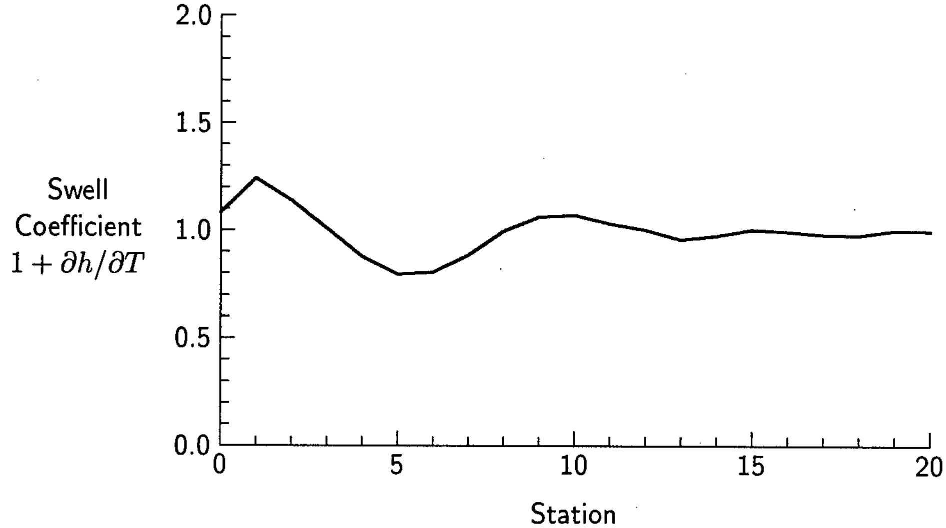


Figure 3: Swell-Up Correction Factor at 18 knots for Example Frigate

3.3 Control Variables for Hydrodynamic Coefficients

Control variables for hydrodynamic coefficients are given in input Record (e). The variable SAVEHY controls storage of sectional hydrodynamic coefficients to a disk file. Computation of hydrodynamic coefficients is typically the most computationally intensive part of a SHIPMO7 run; thus, the user can save much time by using previously computed coefficients if the ship draft and trim remain constant for successive runs. If hydrodynamic coefficients from a previous run are being used, SHIPMO7 checks to ensure that the trim condition is the same for the current run and the stored coefficients.

The control variable HYMETHOD determines whether the boundary element method [22] or conformal mapping method will be used to compute sectional hydrodynamic coefficients. Although the boundary element method takes longer than the conformal mapping method, it will give valid results for almost any section shape. In contrast, the conformal mapping method is limited to sections that can be described by a Lewis form (see Figure 4). Note that previous SHIPMO documentation mistakenly stated that the code could apply the conformal mapping to MIT forms. In general, the greatest differences between boundary element and conformal mapping results will be for roll coefficients. In many cases the conformal mapping method will not adequately model the section geometry to obtain accurate roll hydrodynamic coefficients. Previously, the conformal mapping method had the advantage of no irregular frequencies relative to the close-fit method. The new boundary element method eliminates problems with irregular frequencies.

Hydrodynamic end-effect terms [7] can be included using the input variable HYEND. For consistency with load computations, all hydrodynamic end-effect terms should be included by setting HYEND to LATLONG. Based on a review of References 26 and 27, the SHIPMO sway and yaw hull circulatory force terms described by Schmitke [8] have been eliminated but are replaced by end-effect terms when HYEND is set to SWAYYAW, LAT, or LATLONG.

If the control variable LOWHVCOR is set to HVCOR, then heave hydrodynamic coefficients

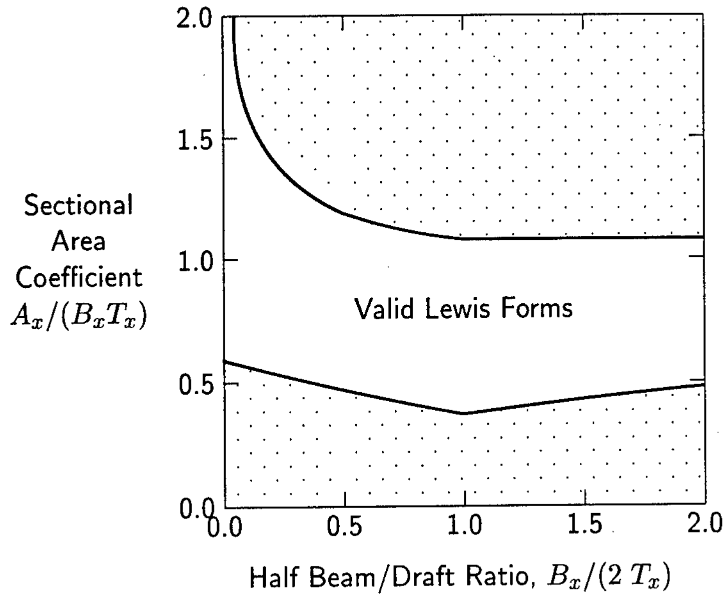


Figure 4: Range of Sectional Area Coefficients for Lewis Forms (from Reference 23)

for surface piercing sections at low encounter frequency will be approximated using a method described in Reference 22. The hydrodynamic theory deteriorates as encounter frequency approaches zero for a heaving surface-piercing body; thus, LOWHVCOR should generally be set to HVCOR.

3.4 Encounter Frequencies

Record (f) gives minimum, maximum, and increment values for encounter frequencies of SHIPMO hydrodynamic coefficients. The encounter frequency range should span the range between where hydrodynamic coefficients approach their respective zero and infinite frequency limits. For a frigate, a suitable encounter frequency range is 0.2 - 6.0 rad/s.

SHIPMO7 introduces low and high frequency approximations described in Reference 22 for hydrodynamic coefficients and velocity potentials. Furthermore, SHIPMO7 introduces a new approach for solving ship motions at low encounter frequencies. Encounter frequencies can approach zero in following seas, as indicated by the following equation:

$$\omega_e \;=\; |\omega \,-\, k\,U\,\cos\beta_s| \tag{3.2}$$

where ω is wave frequency, k is wavenumber, and β_s is the sea direction relative to the ship forward speed (see Figure 5). SHIPMO assumes all computations are for deep water, giving the following relationship between wavenumber and wave frequency:

$$k \;=\; \frac{\omega^2}{g} \tag{3.3}$$

Strip theory predictions of hydrodynamic coefficients and forces deteriorate as encounter frequency approaches zero because of inherent limitations in the theory. The absence of restraining forces in surge, sway, and yaw also causes problems with motion predictions at low

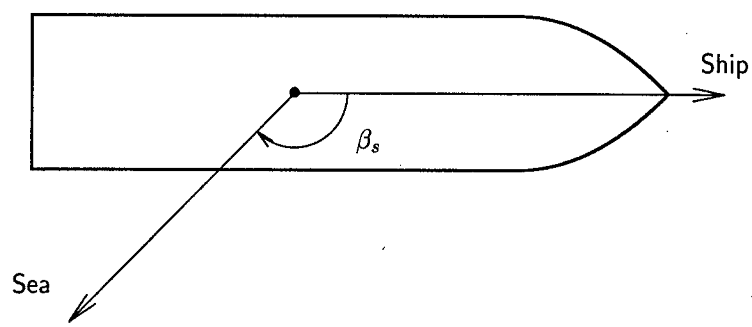


Figure 5: Definition of Sea Direction Relative to Ship Heading

encounter frequencies. Previous versions of SHIPMO adjust the encounter frequency but not the wave frequency if the encounter frequency is less than the minimum value specified by the user. This approach can cause motions at low encounter frequencies to be quite sensitive to the input minimum encounter frequency. In SHIPMO7, the lowest encounter frequency at which ship motions are computed is:

$$\omega_{e-o} \quad = \quad 0.5\sqrt{\frac{g}{L}} \tag{3.4}$$

If the wave frequency ω gives an encounter frequency lower than ω_{e-o}, then the motions and loads are interpolated from values at wave frequencies with encounter frequencies equal to or greater than ω_{e-o}. All sea loads and translational motions (surge, sway, and heave) are assumed to be linear functions of wave frequency, while rotational motions (roll, pitch, yaw, rudder, and stabilizer) divided by wavenumber k are assumed to be linear functions of wave frequency. This interpolation scheme requires motion predictions to include wave frequencies with encounter frequencies equal to or greater than ω_{e-o}.

3.5 Wave Spectra

Record (g) allows the user to select from a large variety of ocean wave spectra, which are presented here for reference. Representative wave heights and periods for the North Atlantic are shown in Table 1.

3.5.1 Quadratic Regression Spectrum

The quadratic regression spectrum is based on observed wave records at station India in the North Atlantic [29]. Input parameters are significant wave height H_s and energy-averaged wave period T_{-1}, defined as:

$$T_{-1} \quad = \quad \frac{\int_0^\infty T\, S(T)\, dT}{\int_0^\infty S(T)\, dT} \tag{3.5}$$

Table 1: Sea State Parameters for the North Atlantic (reproduced from Reference 28)

Sea State Number	Significant Wave Height (m)		Sustained Wind Speed (knots)		Percentage Probability of Seastate	Peak Wave Period	
	Range	Mean	Range	Mean		Range	Most Probable
0 - 1	0 - 0.1	0.05	0 - 6	3	0.7	-	-
2	0.1 - 0.5	0.3	7 - 10	8.5	6.8	3.3 - 12.8	7.5
3	0.5 - 1.25	0.88	11 - 16	13.5	23.7	5.0 - 14.8	7.5
4	1.25 - 2.5	1.88	17 - 21	19	27.8	6.1 - 15.2	8.8
5	2.5 - 4	3.25	22 - 27	24.5	20.6	8.3 - 15.5	9.7
6	4 - 6	5	28 - 47	37.5	13.1	9.8 - 16.2	12.4
7	6 - 9	7.5	48 - 55	51.5	6.1	11.8 - 18.5	15.0
8	9 - 14	11.5	56 - 63	59.5	1.1	14.2 - 18.6	16.4
> 8	> 14	> 14	> 63	> 63	0.05	18.0 - 23.7	20.0

where T is wave period and $S(T)$ is spectral energy density. The spectral energy $S(\omega)$ is evaluated from a non-dimensional database as follows:

$$S(\omega) = \begin{cases} 0 & \text{for } \omega < 0.05\,\omega_{-1} \\ f(H_s, T_{-1}) & \text{for } 0.05\,\omega_{-1} \leq \omega \leq 4\,\omega_{-1} \\ 0 & \text{for } \omega > 4\,\omega_{-1} \end{cases} \tag{3.6}$$

where $\omega_{-1} = 2\pi/T_{-1}$. For fully-developed seas, the peak wave period T_p used as input for the Bretschneider spectrum can be related to the energy averaged period as follows:

$$T_p = 1.166\,T_{-1} \tag{3.7}$$

3.5.2 Bretschneider Spectrum

SHIPMO uses the Bretschneider spectrum taken from the 15th International Towing Tank Conference (ITTC) [30] as follows:

$$S(\omega) = \frac{487\,H_s^2}{T_p^4\,\omega^5}\,\exp\left[\frac{-1948}{T_p^4\,\omega^4}\right] \tag{3.8}$$

The Bretschneider spectrum can also be expressed in terms of the period T_1 corresponding to the energy averaged frequency using the following relationship for fully developed seas:

$$T_1 = 0.773\,T_p \tag{3.9}$$

where T_1 is evaluated as follows:

$$T_1 = 2\,\pi\,\frac{\int_0^\infty S(\omega)\,d\,\omega}{\int_0^\infty \omega\,S(\omega)\,d\,\omega} \tag{3.10}$$

3.5.3 Three Parameter JONSWAP Spectrum

The JONSWAP spectrum models relatively high-peaked spectra typically encountered in fetch-limited regions [30]. The JONSWAP spectrum is obtained by multiplying the Bretschneider spectrum by a peak enhancement factor accounting for fetch-limited conditions. While SHIPMO6 used a two parameter JONSWAP spectrum with $\gamma = 3.3$, SHIPMO7 allows the user to select a value for γ using the following formulation from Reference 31:

$$S(\omega) = \alpha^*\,H_s^2\,\frac{\omega_p^4}{\omega^5}\,\exp\left[-1.25\frac{\omega_p^4}{\omega^4}\right]\,\gamma^\kappa \tag{3.11}$$

$$\kappa = \exp\left[\frac{-(\omega-\omega_p)^2}{2\sigma^2\omega_p^2}\right] \tag{3.12}$$

$$\sigma = \begin{cases} 0.07 & \text{for } \omega \le \omega_p \\ 0.09 & \text{for } \omega > \omega_p \end{cases} \tag{3.13}$$

where ω_p is the peak wave frequency. Goda [32] derived the following approximate expression for the normalization term α^*:

$$\alpha^* = \frac{0.0624}{0.230 + 0.0336\,\gamma - 0.185/(1.9+\gamma)} \tag{3.14}$$

3.5.4 Ochi and Hubble Six Parameter Spectrum

The Ochi and Hubble 6 parameter spectrum [33] models collinear swell and sea components as follows:

$$S(\omega) = \frac{1}{4}\sum_{i=1}^{2}\frac{\left[\left(\frac{4\lambda_i+1}{4}\right)\,\omega_{p_i}^4\right]^{\lambda_i}\,\zeta_i^2\,\exp\left[-\left(\frac{4\lambda_i+1}{4}\right)\left(\frac{\omega_{p_i}}{\omega}\right)^4\right]}{\Gamma(\lambda_i)\,\omega^{(4\lambda_i+1)}} \tag{3.15}$$

where λ_i, ζ_i, and ω_{p_i} are the spectra shape parameter, significant wave height, and peak frequency for component i. If only one of the two components is considered and the shape parameter λ_i equals one, then the six parameter spectrum is equivalent to the Bretschneider spectrum.

3.5.5 Input Unidirectional Spectrum

SHIPMO7 can read an input unidirectional spectrum from a specified file giving successive data pairs of wave frequency and spectral energy density.

3.5.6 Ten Parameter Directional Spectrum

The ten parameter spectrum [34, 35], which was originally proposed by Hogben and Cobb [36], is a directional extension of the Ochi and Hubble six parameter spectrum. Each of the swell and sea components is multiplied by its own directional spreading function as follows:

$$M_i(\nu) = A(P_i) \cos^{2P_i}\left(\frac{\nu - \nu_{m_i}}{2}\right) \qquad i = 1, 2 \tag{3.16}$$

where ν is the compass direction (from) of the directional contribution, and P_i and ν_{m_i} are the directional spread parameter and mean compass direction (from) for component i. The normalization factor $A(P_i)$ is expressed as:

$$A(P_i) = \frac{2^{(2P_i-1)}\,\Gamma^2(P_i+1)}{\pi\,\Gamma(2P_i+1)} \qquad i = 1, 2 \tag{3.17}$$

3.5.7 Hindcast Spectrum

Directional spectra from the Offshore Data Gathering Program (ODGP) hindcast model [34] can be used by SHIPMO7. A complete description of hindcast spectral data files is given in Appendix A.4, and Appendix A.5 shows a sample hindcast spectrum data file.

3.5.8 User Input Directional Spectrum

User input directional spectra can be read by SHIPMO7 based on the format given in Appendix A.6.

3.6 Sea Directions and Spreading Angle for Seaways with a Principal Sea Direction

For the regular, quadratic, Bretschneider, JONSWAP, Ochi-Hubble, and user input unidirectional spectra, waves approach from a principal direction, with the possibility of spreading about the principal direction. The user provides input sea directions and a sea spreading angle in Records (g1) and (g2). Input sea directions are given according to the convention of Figure 5.

If there is an irregular seaway with directional spreading, then the wave energy is distributed among directions on either side of the principal wave direction within SPREADANG degrees. The unidirectional spectral density is multiplied by the following directional spreading function to obtain the directional spectral density:

$$G(\theta) = \frac{1}{\gamma_s}\cos^2\left(\frac{\theta}{\gamma_s}\frac{\pi}{2}\right) \qquad \text{for } |\theta| \le \gamma_s \tag{3.18}$$

$$G(\theta) = 0 \qquad \text{for } |\theta| > \gamma_s \tag{3.19}$$

where θ is the wave component direction relative to the principal sea direction and γ_s is the spreading angle in radians. A spreading angle of 90 degrees is often used for seakeeping computations.

Computation of motions and loads in short crested seas requires response amplitude operators (RAOs) for a range of sea directions. If the input spreading angle is greater than zero, SHIPMO7 checks the user input sea directions to ensure they satisfy the following conditions:

1. Sea directions must be in ascending order, beginning at zero degrees,
2. The increment between successive sea directions must be no greater than 45 degrees,
3. A sea direction of 180 degrees must be included,
4. If there is an off-center seakeeping position, the sea directions must go to a maximum between 345 and 360 degrees.

3.7 Sea Directions for Directional Spectra without a Principle Heading

For the ten parameter, ODGP hindcast, and user input directional spectra, SHIPMO computes regular wave RAOs at sea direction increments of 15 degrees. Output RMS values are given for ship compass heading (shown as χ in Figure 6). For a wave component coming from compass heading ν, the sea direction relative to the ship forward speed is:

$$\beta_s \;=\; \nu + 180^\circ - \chi \tag{3.20}$$

where ν is the wave component compass direction (from).

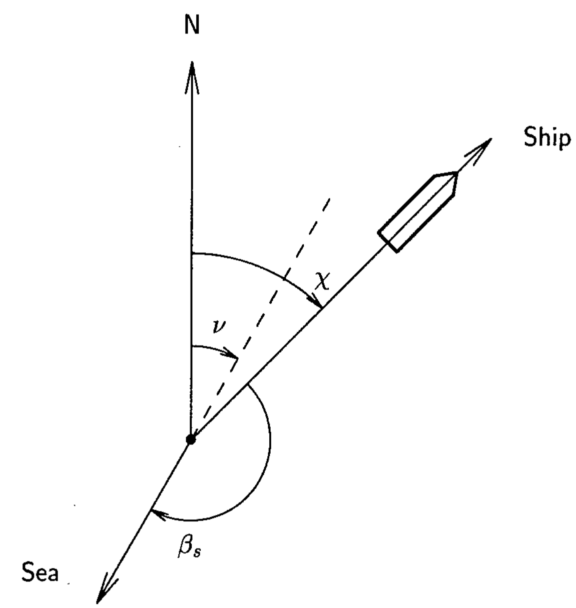


Figure 6: Definition of Sea Direction and Ship Heading Relative to Compass

3.8 Vertical Coordinates Relative to Ship Baseline

Input vertical coordinates are given relative to the ship baseline shown in Figure 7. Output vertical coordinates are given relative to a horizontal datum located at the midships draft, waterline, or center of gravity (CG). The transformation from a baseline referenced vertical coordinate to a CG referenced value is:

$$z = z_{bl} - \overline{KG} + x \frac{TRIMST}{L} \tag{3.21}$$

where z_{bl} is the elevation relative to the baseline, $\overline{KG}$ is the height of the CG above the baseline, and $TRIMST$ is the trim by the stern. The elevation relative to the waterline is:

$$z_{wl} = z_{bl} - DRAFTMID + \left(x + \frac{L}{2} - LCGFP\right) \frac{TRIMST}{L} \tag{3.22}$$

where $DRAFTMID$ is baseline draft at midships and $LCGFP$ is the distance for the forward perpendicular to the longitudinal centre of gravity.

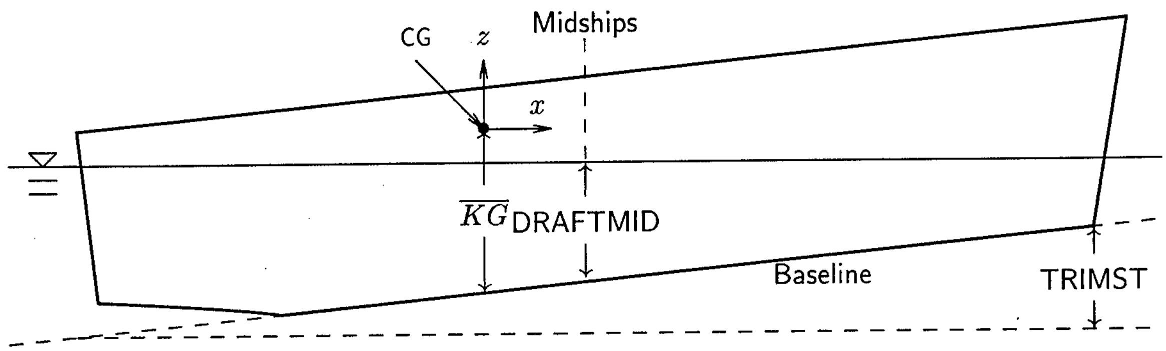


Figure 7: Ship Vertical Coordinates

3.9 Roll Stiffness and Inertial Properties of Ship

Input Records (j) to (k4) include various parameters for describing the ship roll stiffness and inertial properties. To obtain accurate roll and pitch predictions, the roll and pitch natural frequencies of the SHIPMO output must agree with values for the actual ship. If loads are being computed, the roll and pitch radii of gyration given in Records (j) to (k4) must also agree with the values based on the input mass distribution given in Records (n2) to (n6). To assist with checking of input, SHIPMO outputs ship inertial properties based on input values for the entire ship and for the sectional mass distribution. In practice, ship and sectional roll gyradii are difficult to measure and usually have significant errors. Often the roll natural frequency provides the most reliable information for determining the roll inertial properties. If sea loads are being computed, then the sectional roll radii of gyration (Records (n4), (n5), and (n6)) should be checked and possibly modified to obtain agreement between the ship roll gyradius based on natural frequency and the gyradius based on the sectional mass distribution.

3.10 Hull Form Definition

Records (l) to (l4) describe the hull geometry using either input offsets or sectional coefficients. Input stations are numbered with station 0 at the forward perpendicular and with station NST-1 (typically station 20) at the aft perpendicular, where NST is the total number of stations.

If lateral plane motions are of importance, then input offsets should be used to describe the hull sufficiently accurately for roll motion predictions. Figure 4 shows the range of parameters for which Lewis forms will provide a valid description of a section.

Figure 8 shows input section offsets, which are typically given up to the deck edge. The last input offset for each section must be either above the design waterline or at the centreline. SHIPMO7 will accept a maximum of 30 input offset points per station.

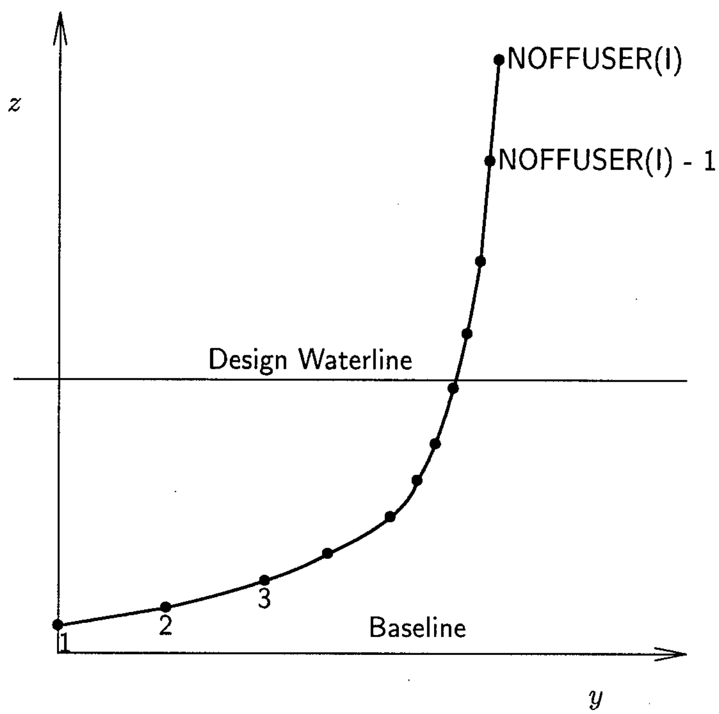


Figure 8: Input Section Offsets

3.11 Trim Definition

Records (m) to (m2) describe the trim condition in terms of draft and trim, or displacement and longitudinal centre of gravity (LCG) location. If the hull is described using sectional coefficients, then the trim condition must be specified as draft and trim by stern.

For consistency during sea loads computations, the hull displacement and LCG location based on hydrostatics must agree with values based on the input mass distribution given by Records (n2) to (n6). Consequently, the trim condition should be defined using the the displacement and LCG location based on the input mass distribution, which is given in the SHIPMO output. The vertical center of gravity location specified by KG in Record (j) should also agree with the KG value from the mass distribution for sea loads.

3.12 Mass Distribution for Sea Loads Computations

Sea loads computations require an accurate description of the ship mass distribution in Records (n2) to (n6). The input weight (British tons) or mass (metric tonnes) for each interior station represents the mass within half a station of either side of the station. For example, the mass for station 1.0 represents the mass between station 0.5 and 1.5. For the two end stations, (e.g. stations 0 and 20) the input mass represents the mass within half a station and within the perpendiculars (e.g. the mass for station 0 includes the mass from stations 0.0 to 0.5, and the mass for station 20 includes the mass from 19.5 to 20.0). Records (n5) and (n6) are used to model additional masses forward of the forward perpendicular and aft of the aft perpendicular.

Figure 9 shows the mass distribution for the frigate in the sample output of Appendix B.2. For computations within SHIPMO7, the masses for each station are assumed to be uniformly distributed between mid-stations. This method produces more consistent results than more complex techniques such as Simpson's rule for ships having non-smooth mass distributions.

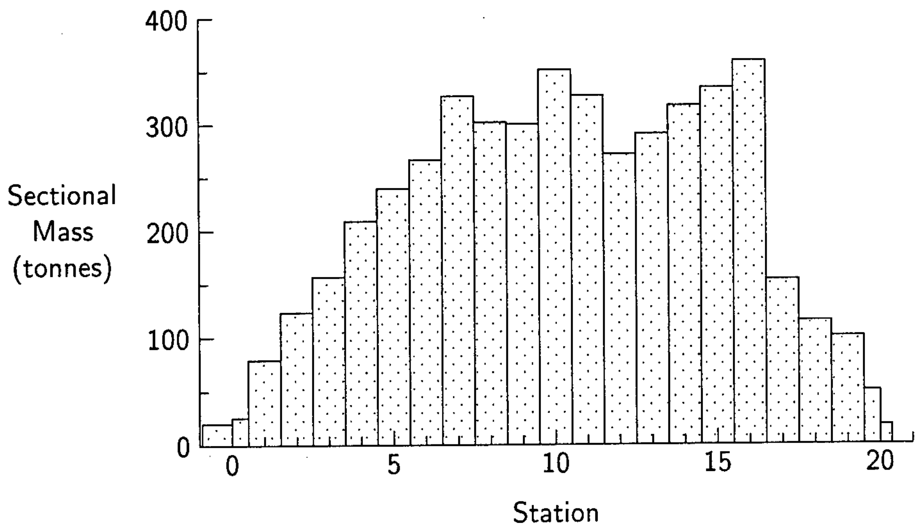


Figure 9: Mass Distribution for Example Frigate

Perhaps the greatest challenge in preparing the input mass distribution is to obtain accurate values for sectional $\overline{KG}$ and roll gyradius. Fortunately, lateral plane loads are typically of less concern than vertical plane loads. If insufficiently accurate information is available for sectional $\overline{KG}$ roll gyradius values, then the user can enter approximate values with the understanding that the resulting lateral plane load predictions will be unreliable. SHIPMO7 can set default values for sectional $\overline{KG}$ and roll gyradius. If all input sectional $\overline{KG}$ values are zero, then SHIPMO sets each sectional $\overline{KG}$ value to the ship $\overline{KG}$ value given in input Record (j). If all input sectional roll gyradius values are zero, then SHIPMO uses the following relationship for estimating the roll gyradius of each section about its centre of gravity:

$$r_{xx-i} = k_r \sqrt{\frac{m_i}{l_i}} \tag{3.23}$$

where m_i is the mass of section i and l_i is the length of section i. The constant k_r is set such that the ship roll gyradius integrated over all ship sections is equal to the gyradius based on input Records (k) to (k4). Although this approach gives rational estimates of roll gyradii, there exists great uncertainty regarding the accuracy of estimated gyradii and resulting lateral plane loads; thus, the resulting lateral plane load predictions should be considered as approximate.

3.13 Seakeeping Positions

SHIPMO computes responses in regular seas for seakeeping positions specified in Records (o) to (o6). Computations are available for motions, slamming forces, and incidence of motion-induced interruptions.

3.13.1 Slamming Parameters

SHIPMO's slamming calculations are based largely on the work of Ochi and Motter [37] and Stavovy and Chuang [38]. The maximum slam pressure at the keel is related to a sectional slamming form factor as follows:

$$p_{max} = \frac{1}{2} \rho V_r^2 \times SLFORM \tag{3.24}$$

where V_r is the relative impact velocity upon impact. For calculating slamming force per unit length, SHIPMO uses the assumption from Reference 37 that the sectional slamming pressure goes from a maximum value at the keel to zero at a specified elevation above the keel, as illustrated in Figure 10. The elevation of zero slam pressure is typically taken as being 1/10 the sectional draft above the keel. The sectional slamming force per unit length is computed using an effective slamming pressure width as follows:

$$F_{max} = p_{max} \times SLWIDTH \tag{3.25}$$

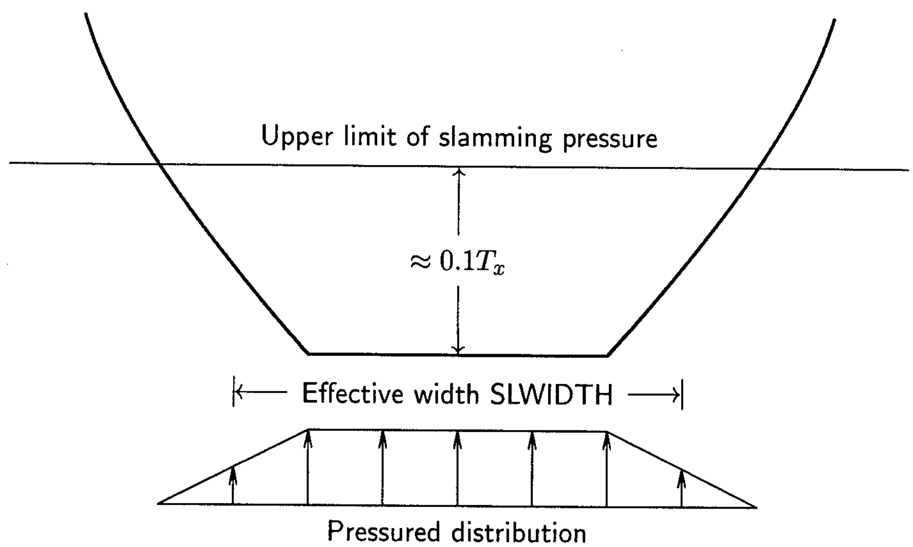


Figure 10: Assumed Slamming Pressure Distribution for Sectional Force Computation

The user can provide input values for the slamming form factor and effective width. Alternatively, SHIPMO can compute the form factor and effective width based on the lower sectional geometry provided by the user. If the geometry is input as a wedge as shown in Figure 11, then SHIPMO uses a fit to experimental data given by Stavovy and Chuang for computing the form factor. Stavovy and Chuang's method has been slightly modified to impose a form factor limit of 100, which affects sections with deadrise angles smaller than 6 degrees. Using the assumed pressure distribution of Figure 10, the effective pressure width for a wedge is:

$$SLWIDTH = \frac{SLHEIGHT}{\tan(DEADR)} \tag{3.26}$$

where $SLHEIGHT$ is the height above the keel at which the slamming pressure goes to zero and $DEADR$ is the deadrise angle.

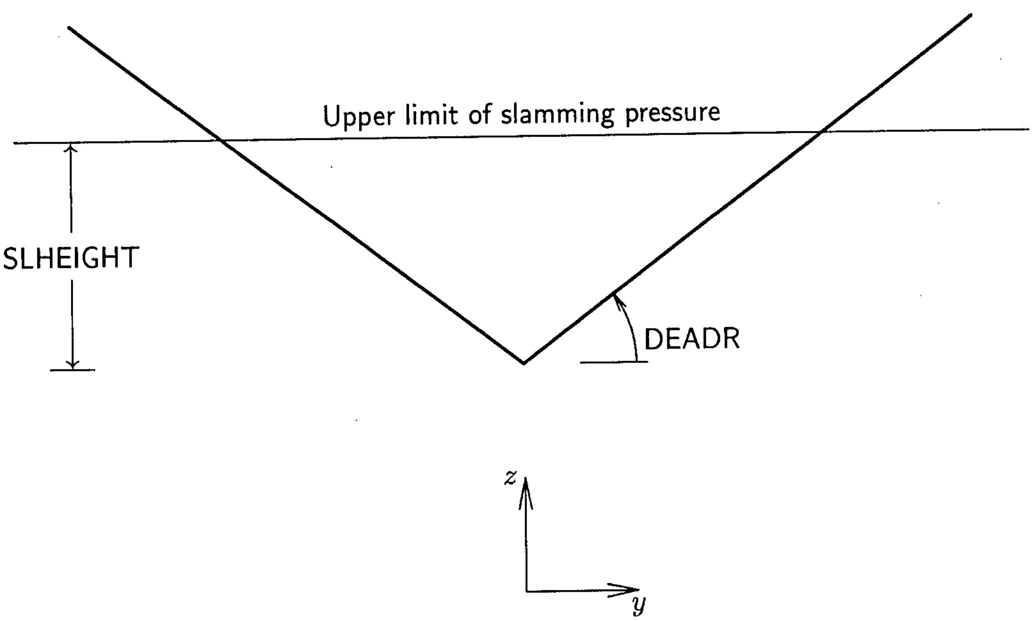


Figure 11: Input Wedge Geometry for Computing Slamming Form Factor

If the user inputs the geometry near the keel as offsets, then SHIPMO uses Ochi and Motter's method to compute slamming form coefficients. Figure 12 illustrates input offsets for computing the slamming form factor.

Experimental results indicate that slamming pressures can be highly sensitive to ship section geometry, size of area of pressure measurement, and structural properties of impact area; thus, predicted slamming pressures and forces should be considered to be only approximate values. Published values indicate that slamming form factors can lie within an extremely large range of between less than 1 and greater than 300; however, the actual slamming coefficient for a ship section in a seaway will rarely exceed 30. Slamming coefficients computed using input offsets near the keel and Ochi and Motter's method are likely smaller in magnitude and more realistic than values computed for a wedge based on Stavovy and Chuang. Figure 13 shows slamming coefficients predicted by SHIPMO for wedge sections based on Stavovy and Chuang's method

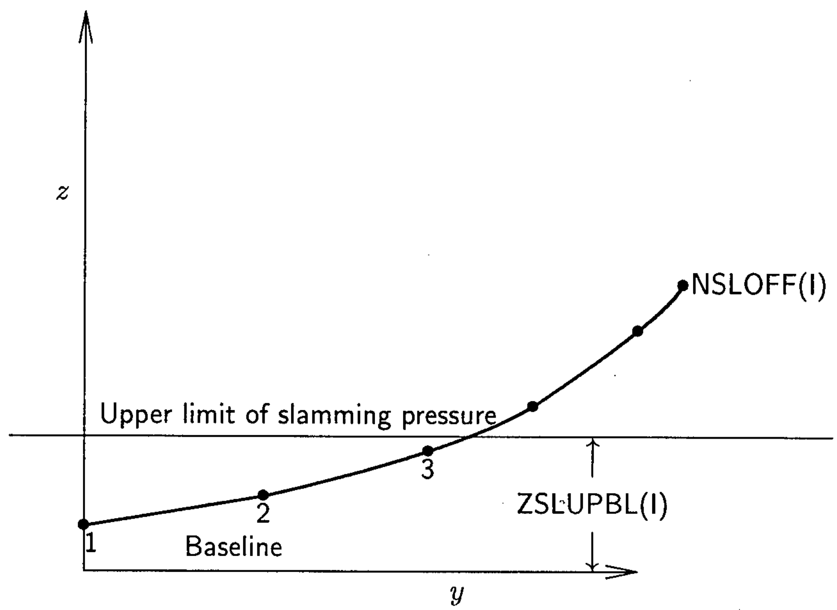


Figure 12: Input Sectional Offsets Near Keel for Computing Slamming Form Factor

and Ochi and Motter's method. For wedge sections with large deadrise angles (greater than 50 degrees), Ochi's method fails to provide results because of numerical problems.

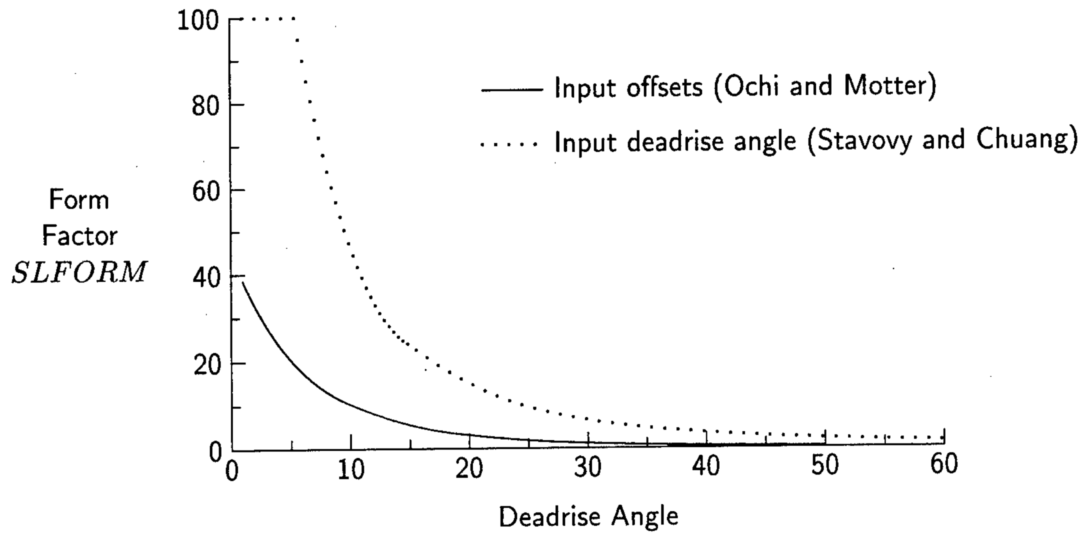


Figure 13: Slamming Pressure Coefficients for Wedge Sections

3.13.2 Motion-Induced Interruptions

SHIPMO can compute ship-referenced forces, and estimate the incidence of motion-induced interruptions (MIIs) at seakeeping positions. The incidence of MIIs, which can be tipping or sliding events, is estimated using tipping or sliding estimator functions which include the contributions of vertical forces as well as the forces parallel to the deck. The SHIPMO5 manual [5] gives a detailed treatment of ship-referenced forces, estimator functions, and motion-induced interruptions.

The incidence of tipping events for a person or object depends upon the tipping coefficient s/h, where s is the half stance width and h is the height above deck of the centre of gravity, as shown in Figure 14. The tipping coefficient is usually dependent upon the direction of tipping. To evaluate the incidence of sliding events, the tipping coefficient s/h can be replaced by the static coefficient of friction μ_s. Table 2 gives representative tipping and sliding coefficients from Reference 11 and unpublished data. The wide range of friction coefficients suggests the incidence of sliding can vary greatly, depending on sliding surface conditions. Because the static coefficient of friction for a person is usually greater than the tipping coefficient, a person will usually tip more easily than slide. Table 3, reproduced from Reference 10, gives risk levels associated with motion-induced interruptions (MIIs).

3.14 Appendages

Appendages have a significant influence on ship motions in the lateral plane. For roll, appendage forces can be particularly significant because of the relatively small excitation, added mass, and damping forces acting on the hull. Schmitke [8] gives a detailed description of the

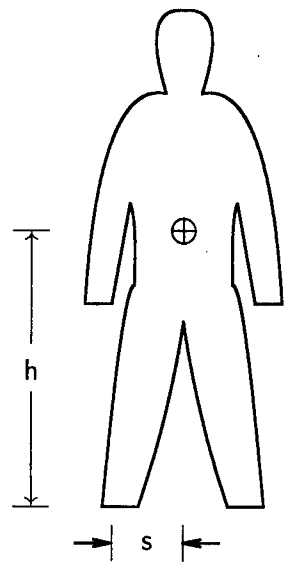


Figure 14: Model for Person Standing on Deck

Table 2: Representative Tipping and Sliding Coefficients

Tipping in the forward direction	0.17
Tipping in the sideways direction	0.25
Sliding, person standing on dry deck	0.7
Sliding, chair on interior floor	0.19
Sliding, helicopter for various deck conditions	0.2 - 0.8

Table 3: MII Risk Levels

Risk Level	MIIs per Minute
1. possible	0.1
2. probable	0.5
3. serious	1.5
4. severe	3.0
5. extreme	5.0

hydrodynamic forces acting on ship appendages. Figure 15 shows the general dimensions for a foil appendage such as a rudder, stationary foil, or stabilizing fin. SHIPMO7 introduces a new convention for appendage dihedral angles, as illustrated in Figure 15. For surface ships, foil dihedral angles are almost always less than zero with the angle convention of Figure 15. Figure 16 shows example dihedral angles for arms of a propeller shaft bracket.

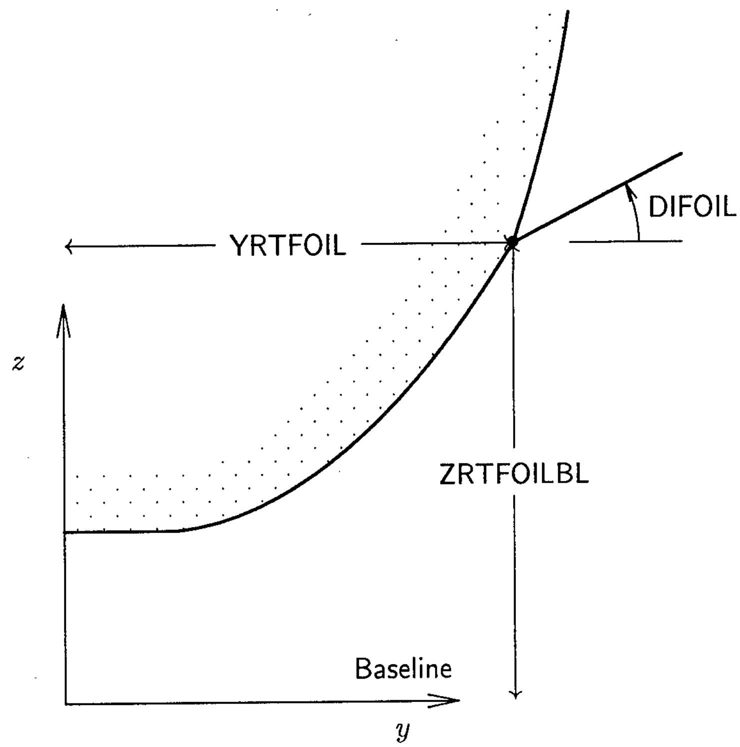


Figure 15: Input Dimensions for Foil Appendage

At each ship speed, SHIPMO multiplies the input lift coefficients for all foils (rudder, stationary foils, and stabilizer fins) by hull boundary layer correction factors (less than 1.0) to obtain effective lift coefficients. For a rudder in the propeller slipstream, the correction factor is set to 1.0 regardless of ship speed.

3.14.1 Bilge Keels

SHIPMO considers contributions from the bilge keels to roll added mass, viscous roll damping, and lift roll damping. Figure 17 illustrates a ship section with some of the bilge keel input parameters of Records (p1) and (p2). Figure 18 shows longitudinal bilge keel inputs for the example ship of Appendices A.2 and B.2.

The bilge keels are treated as low aspect ratio foils for calculation of lift forces [8, 26]. Consequently, if two bilge keels pairs are separated by only a very small longitudinal distance (e.g. less than the bilge keel breadth), they should be treated as a single bilge keel pair to predict the correct lift force.

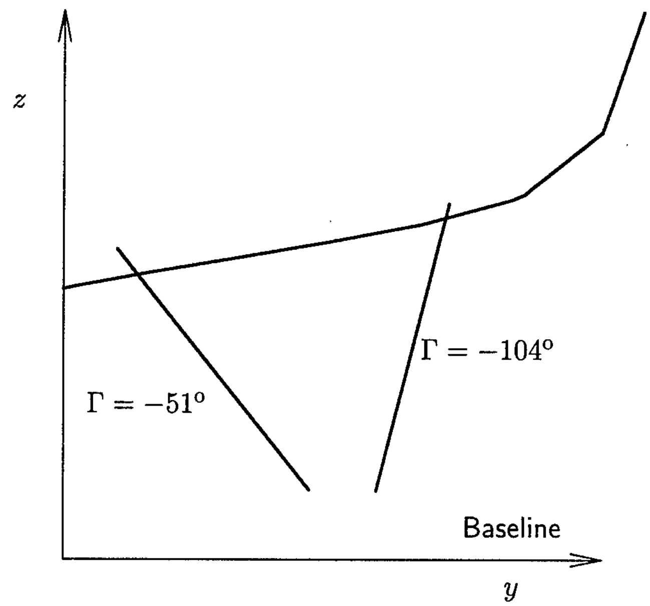


Figure 16: Propeller Shaft Bracket Arms for Example Frigate

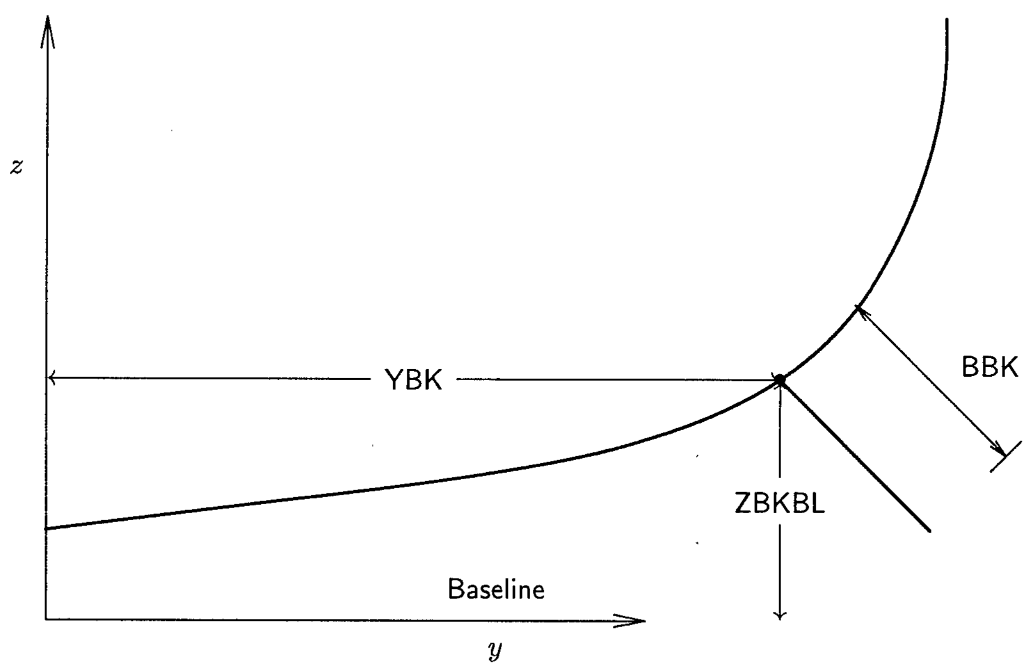


Figure 17: Bilge Keel Inputs

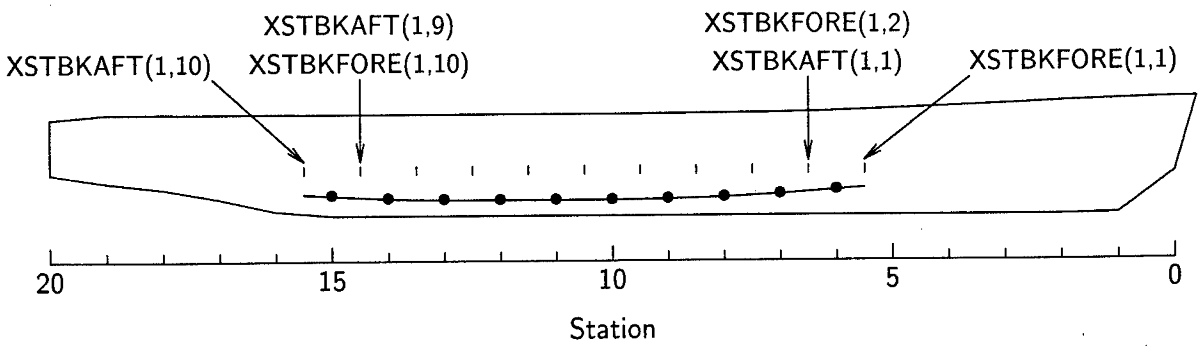


Figure 18: Bilge Keel Longitudinal Inputs for Example Frigate

3.14.2 Skeg

Input Record (q) has dimensions for a triangular skeg as shown in Figure 19. These dimensions are used for computing damping and excitation forces due to lift acting on the skeg. If the skeg is molded into the hull and contributes significantly to the hull hydrodynamic forces, then the skeg should also be included in the hull offsets. For example, Canada's Maritime Coastal Defence Vessel (MCDV) has a large skeg molded into the hull.

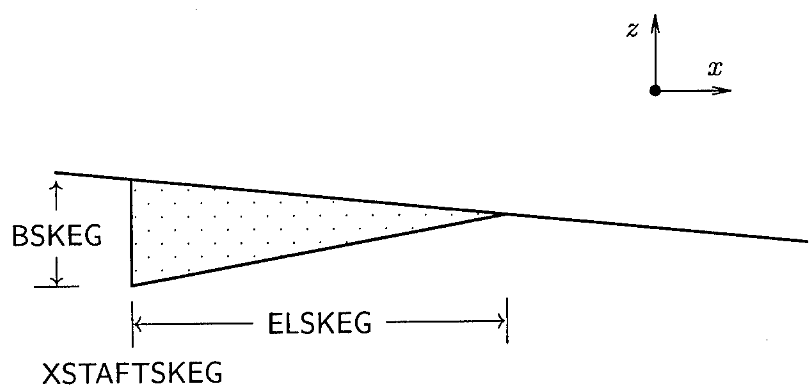


Figure 19: Skeg Inputs

3.14.3 Rudder

SHIPMO can model one or two rudders with dimensions given in input Record (r). Rudders are assumed to be vertical and oriented downward (dihedral angle of -90 degrees).

Records (r1) and (r2) have parameters for the rudder autopilot, which can be set for stabilization of roll and yaw motions. The rudder deflection angle δ responds to a command rudder deflection angle δ_c as follows:

$$\ddot{\delta} + 2\, DAMPRUD \times FREQRUD\, \dot{\delta} + FREQRUD^2\, \delta = FREQRUD^2\, \delta_c \quad (3.27)$$

where $DAMPRUD$ is the dimensionless damping coefficient and $FREQRUD$ is the natural frequency of the rudder control system. The command rudder deflection angle is determined by the roll and yaw rudder gains and the ship roll and yaw motions as follows:

$$\begin{aligned}\delta_c &= RAGNRUD\,\ddot{\eta}_4 + RVGNRUD\,\dot{\eta}_4 + RGNRUD\,\eta_4 \\ &\quad + YAGNRUD\,\ddot{\eta}_6 + YVGNRUD\,\dot{\eta}_6 + YGNRUD\,\eta_6 \end{aligned} \tag{3.28}$$

The rudder autopilot will have a command angle of zero if the wave encounter frequency is outside of the range between the system lower and upper frequency limits $FREQLRUD$ and $FREQHRUD$.

3.14.4 Stationary Foils

Stationary foils (Records (s) and (s1)) can be used to model propeller shaft brackets and other static foils appended to a ship. Figure 16 illustrates a propeller shaft bracket consisting of two stationary foils for the example frigate of Appendices A.2 and B.2.

3.15 Fin Stabilization

Input Records (u) to (u2) allow the user to model roll stabilization using active fins. Unlike previous versions, SHIPMO7 ignores interference effects from other fins and bilge keels. Reference 39 indicates that these interference effects are highly nonlinear, and are thus difficult to model by SHIPMO. If the program user wishes to model interaction effects, then the SHIPMO7 input fin lift coefficients should be modified based on experimental or numerical studies.

The control system for the stabilizing fins is modelled as:

$$\ddot{\beta} + 2\,DAMPFIN \times FREQFIN\,\dot{\beta} + FREQFIN^2\,\beta = FREQFIN^2\,\beta_c \tag{3.29}$$

where $DAMPFIN$ is the dimensionless damping coefficient and $FREQFIN$ is the natural frequency of the fin control system. The command fin deflection angle is determined by the roll fin gains and the ship roll motion as follows:

$$\beta_c = RAGNFIN\,\ddot{\eta}_4 + RVGNFIN\,\dot{\eta}_4 + RGNFIN\,\eta_4 \tag{3.30}$$

The stabilizing fins will have a command angle of zero if the wave encounter frequency is above the high frequency limit $FREQHFIN$.

3.16 U-Tube Tank Stabilization

SHIPMO can also model roll stabilization using a U-tube tank. Figure 20 illustrates input parameters which are given in Record (v). Schmitke [40] describes the theory used in SHIPMO, which is based on References 41, 42, and 43.

The tank valve resistance coefficient for a U-tube tank is assumed to vary with wave encounter

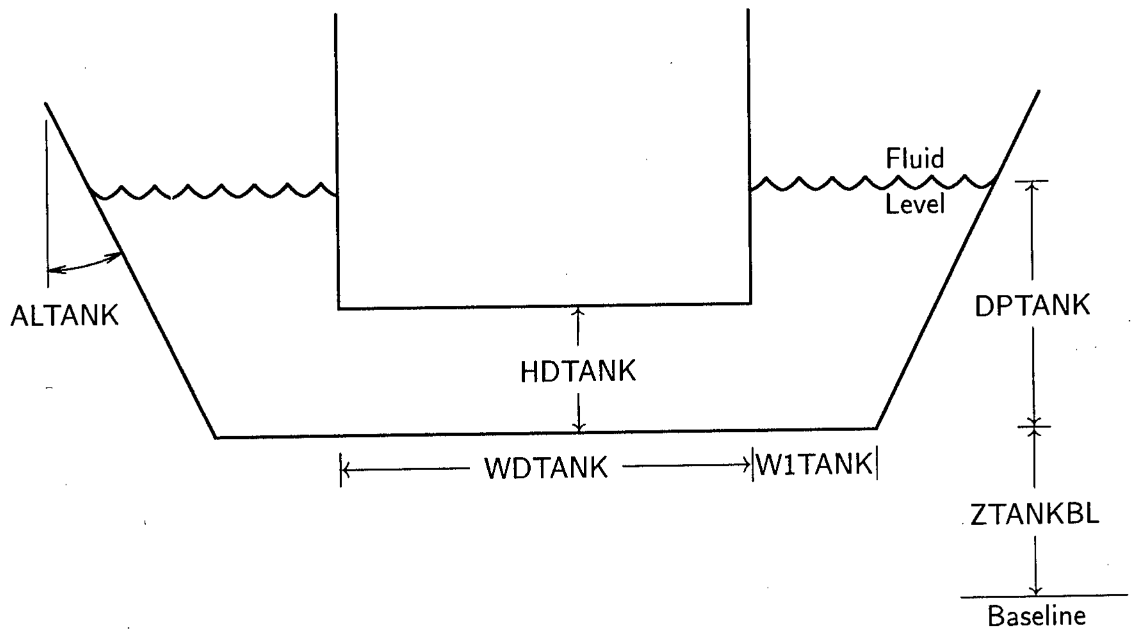


Figure 20: Inputs for U-Tube Roll Stabilization Tank

frequency as follows:

$$\lambda_s = \begin{cases} RESISTBTANK \text{ for } \omega_e \geq BFREQTANK \\ RESIST0TANK \\ \quad + (RESISTBTANK - RESIST0TANK)\ \omega_e/BFREQTANK \\ \quad \text{for } \omega_e < BFREQTANK \end{cases} \tag{3.31}$$

where $RESISTBTANK$ is the resistance coefficient at the break frequency $BFREQTANK$, and $RESIST0TANK$ is the the resistance coefficient at zero frequency. This scheme enables modelling of a controllable passive tank in which damping is effectively increased at low frequencies in order to avoid amplification of roll by the stabilizer in quartering seas. For example, satisfactory simulation of a controllable passive tank installed on a destroyer has been achieved by setting $RESISTBTANK = 15$, $BFREQTANK = 0.9ROLLNF$, and $RESIST0TANK = 25RESISTBTANK$, where $ROLLNF$ is the ship roll natural frequency.

4 Running SHIPMO7

The SHIPMO program is run by simply starting the executable program file. Input is read from file "shipmo7.inp" and output is written to file "shipmo7.out". The program source code can be compiled and run on most systems with a Fortran 77 compiler. DREA supports versions on Silicon Graphics, Digital Alpha, and Intel-based personal computer platforms. The code should be able to run within 8 MB of memory. For typical ship cases, SHIPMO7 will complete execution within minutes on slower platforms and within seconds on faster workstations. Evaluation of sectional hydrodynamic coefficients using the boundary element method requires the majority of computational effort in most cases.

SHIPMO7 outputs warning and error messages to both the terminal and to the output file. An error message will cause the program run to terminate, while a warning will still allow program execution.

Limits on maximum values of many SHIPMO7 input variables are set by a Fortran PARAMETER statement in file "param.cmn", which is included in many SHIPMO7 subroutines using a Fortran INCLUDE statement. Table 4 gives parameters set in file "param.cmn". If a user input value exceeds the capacity of the SHIPMO7 parameters, then the program writes a descriptive error message and terminates. If the user wishes to increase the capacity of SHIPMO7, he can adjust values in "param.cmn" and re-compile the program.

Table 4: SHIPMO7 Maximum Parameters

Parameter	Description	Value
NBKPAIRMAX	Number of bilge keel pairs	5
NENFREQMAX	Number of encounter frequencies	40
NFINPAIRMAX	Number of stabilizing fin pairs	4
NFOILPAIRMAX	Number of stationary foil pairs	4
NFREQSPUNIMAX	Number of frequencies for input unidirectional spectrum	101
NOFFMAX	Number of sectional offsets	30
NPOSMAX	Number of seakeeping positions	10
NSEADIRMAX	Number of sea directions	36
NSEAWAYMAX	Number of seaways	10
NSEGMAX	Number of sectional segments (should be NOFFMAX-1)	29
NSLOFFMAX	Number of sectional slamming offsets	11
NSTLOADMAX	Number of stations for sea loads	21
NSTMAX	Number of ship stations	21
NWVFREQMAX	Number of wave frequencies	40

5 Program Output

Appendix B.2 gives sample output from SHIPMO7. This section gives information for interpreting results given in the SHIPMO output.

Most of the SHIPMO output is given in columns and can be easily imported to spreadsheet programs such as Microsoft Excel for plotting and data analysis.

5.1 Echo of User Input and Ship Properties

The program output begins with the program name and echo of the run title with the date and time appended to it. The echo of the user input can be used for checking that all input variables have been entered and read correctly. Any default parameters set by the program are echoed in the output. For bilge keels, the root offsets and nearest points on the hull surface are printed to enable checking that the bilge keel root lies on or near the hull surface. Offsets for the trimmed ship are given up to the waterline. ASCII plots of the hull body plan and appendages are also given for checking input.

Ship hull coefficients are output relative to the beam and draft at midships. For computing hull coefficients, the draft at midships is assumed to be equal to the depth of the baseline at midships. The actual sectional draft at midships will differ from the output midships draft if the keel elevation is different from the baseline at midships. Output hull coefficients include the block, prismatic, and vertical prismatic coefficients, which are defined as:

$$C_B = \frac{\nabla}{L\,B\,T} \tag{5.1}$$

$$C_P = \frac{\nabla}{L\,A} \tag{5.2}$$

$$C_{VP} = \frac{\nabla}{A_{wp}\,T} \tag{5.3}$$

where ∇ is the displacement volume, B is midships beam, T is midships draft (assumed to be depth of baseline at midships), A is midships sectional area, and A_{wp} is waterplane area. The output table of sectional properties includes actual sectional drafts, which are the depth of the keel ($y = 0$) below the waterline.

If sea loads are being evaluated, then SHIPMO7 outputs the mass distribution parameters for comparison with the ship hydrostatic condition. For acceptable load computations, the input mass distribution should agree with the ship hydrostatic condition. If ship displacement and LCG location have slight differences (less than 3 percent) between the mass distribution and hydrostatics, then the midships draft and trim should be changed to match the mass distribution. The mass distribution should be checked if its parameters differ significantly from the hydrostatic parameters.

Output values for the seakeeping positions include their elevations relative to the baseline, ship CG, and static waterline.

5.2 Wave Spectral Energies

If the computations include irregular seas, then spectral energies are output for the wave frequencies used in motion computations. The significant wave height based on these spectral energies is also given, and is compared with the input significant wave height. If the lowest or highest wave frequencies have significant spectral energies, then the computed significant wave height will likely be less than the input wave height because a significant amount of spectral energy lies outside the input wave frequency range (input Record (d)). The solution to this energy deficit is to expand the input wave frequency range.

5.3 Steady Wave and Swell-Up Coefficient Due to Ship Forward Speed

SHIPMO7 performs a full set of computations for each ship speed. At the beginning of each ship speed, the program outputs the longitudinal distribution of steady wave elevation and swell-up coefficient based on the user input for variables SPEEDCOR and SWELLCOR. These values are used for predictions of relative motions, slamming, emergence, deck wetness, and added resistance in waves.

5.4 Responses in Regular Waves

Ship motions in regular waves and roll damping coefficients are printed if requested by variable OUTRAO of input Record (b). If there is more than one seaway, regular seas responses are only given for the first seaway to minimize unnecessary output. Furthermore, regular wave responses for headings greater than 180 degrees are not output because of symmetry. For responses in regular waves, the heading represents the wave direction (to) relative to the ship speed (i.e. 180^o corresponds to head seas, see Figure 5).

If roll and/or yaw control is provided by the rudder, stabilizing fins, or stabilizing tank, then the program outputs rudder and/or stabilizer motions. Output phases for ship and stabilizer motions are expressed relative to wave elevation at the CG; e.g., sway phase = 90 degrees means sway achieves its maximum positive value at a point on the wave cycle 90 degrees before wave elevation at the CG achieves its maximum positive value. Note that SHIPMO phase angles can be converted to the ITTC convention [30] as follows:

ITTC		SHIPMO
Surge phase	=	Surge phase + 180 degrees
Sway phase	=	Sway phase
Heave phase	=	Heave phase
Roll phase	=	Roll phase + 180 degrees
Pitch phase	=	Pitch phase
Yaw phase	=	Yaw phase

The translational and angular amplitudes of the motions are non-dimensionalized by wave amplitude and wave slope, respectively. Added resistance in regular waves is output if requested by input variable RAWFLAG in Record (c).

The output roll damping coefficients depend upon the echoed roll amplitude. If the program is computing the motions in irregular waves, the echoed roll amplitude for each ship speed and heading is equal to 1.25 times the RMS roll in unidirectional seas with spectral energies from the specified seaway. If only regular wave computations are being performed, then for each heading and wave frequency, the roll angle equals the wave slope (π times the wave steepness specified in Record (h1)) times the roll response per unit wave slope.

If available, SHIPMO prints load responses in regular seas.

5.5 Responses in Irregular Seas

After giving regular seas results for a given ship speed, SHIPMO outputs responses in irregular seas if available. For random processes such as ship motions and loads in irregular seas, SHIPMO gives RMS (root mean square) values and zero-crossing periods, defined as:

$$T_z = 2\,\pi \sqrt{\frac{m_0}{m_2}} \tag{5.4}$$

where m_i is the i'th spectral moment of the process, given by:

$$m_i = \int_0^\infty \omega^i \, S(\omega) \, d\omega \tag{5.5}$$

If a spectrum with a principal wave direction has been selected (quadratic regression, Bretschneider, JONSWAP, Ochi and Hubble 6 parameter, or input unidirectional), seakeeping data are given for unidirectional seas at each of the principal sea directions (headings) specified in Record (g2). Results are given for only long-crested or short-crested seas, depending on the input spreading angle. Output headings are the principal sea direction relative to the ship speed (see Figure 5).

For directional spectra with no principal wave direction, (10 parameter, hindcast, or input directional), output motions are given for the short-crested seaway. Output headings represent the ship compass heading (see Figure 6).

The output RMS values begin with the ship translational and rotational motions at the CG. Motions are also given for the rudder and/or roll stabilizer if they are non-zero. SHIPMO also outputs RMS added resistance in waves if this option has been selected.

Following motions for the ship, motions at seakeeping stations are given. If the user has requested MII computations, then SHIPMO also outputs lateral and longitudinal force estimators at the seakeeping station. These force estimators are often used for predicting forces acting on deck-mounted equipment. SHIPMO prints relative motion results (slamming, deck wetness, emergence) if requested. The output includes draft and freeboard values corrected for the steady wave due to ship forward speed.

Sea loads in irregular seas (if applicable) are the last output values to be given. Because of the large dependence of sea loads on ship size, the units of the output loads vary with the magnitude of the loads.

6 Concluding Remarks

The new version of SHIPMO gives motion and sea load predictions in regular and irregular seas. The program includes several enhancements, including elimination of irregular frequencies and revised input and output. The most significant improvement to the program is the inclusion of sea loads in a consistent manner including appendage forces. The resulting sea load predictions should be able to approach the accuracy of motion predictions.

A SHIPMO7 Input

A.1 Input Records

Detailed descriptions of SHIPMO7 input records are given below. Each new input record or sub-record corresponds to a new file line. The format of the input file may be adjusted by inserting extra blanks between any numerical data, and by placing data from within any particular record on separate lines; however, separate records cannot be combined on a single line.

For lines with input character strings, string variables should be separated by spaces and/or a comma.

Record (a), Eighty Character Title
TITLE (columns 1 - 80)

TITLE	Alphanumeric title (maximum of 80 characters) which is written on output.

Record (b), Control Variables
INSYS, OUTSYS, WATERDEN, SPEEDCOR, SWELLCOR, RAOOUT, OUTPPR (7 character strings)

INSYS — Specifies the system of units used for input data. The two possible inputs are:

BRITISH	British units.
METRIC	Metric units.

OUTSYS — Specifies the system of units used for output data. The two possible inputs are:

BRITISH	British units.
METRIC	Metric units.

WATERDEN — Specifies whether ship is in salt or fresh water. The two possible inputs are:

SALT	Salt water ($\rho = 1.989$ slug/ft^3, 1025.0 kg/m^3).
FRESH	Fresh water ($\rho = 1.940$ slug/ft^3, 1000.0 kg/m^3).

SPEEDCOR — Specifies elevation corrections to be made due to the dynamic waterline generated by the ship forward speed. These corrections are used for relative motion computations, including keel emergence, propeller emergence, slamming, and deck wetness. The three possible inputs are:

NOSPEEDCOR	No corrections are applied.
BOWSPEEDCOR	The forward speed correction is applied fully to the forward half of the ship, and decreases to zero at the stern. This method is most reliable for transom stern ships for which the dynamic waterline prediction deteriorates at the stern.

SPEEDCOR — The forward speed correction is applied to the entire ship. This method should only be used for ships with narrow transoms.

SWELLCOR — Specifies swell-up corrections to be made to relative motion due to interaction between relative motion and the steady forward speed wave. These corrections are used for relative motion computations, including keel emergence, propeller emergence, slamming, and deck wetness. The three possible inputs are:

NOSWELLCOR — No swell-up correction.

BOWSWELLCOR — The swell-up correction is applied fully to the forward half of the ship, and decreases to zero at the stern. This method is most reliable for transom stern ships for which the swell-up prediction deteriorates at the stern.

SWELLCOR — The swell-up correction is applied to the entire ship. This method should only be used for ships with narrow transoms.

OUTRAO — Control variable for program output of regular wave responses. The three possible inputs are:

NORAO — Suppress output of regular wave responses, and of roll damping coefficients.

MOTION — Allow output of regular wave motion and load responses (if applicable). Suppress output of roll damping coefficients.

MODAMP — Allow output of regular wave responses and of roll damping coefficients.

OUTPPR — Control variable governing disk file storage of resulting frequency responses and RMS motions for post-processing. The two possible inputs are:

NOPPR — Disk storage is not used.

OUTPPR — Frequency responses and RMS motions are stored in a sequential disk file for post-processing. The name of the disk file must be specified in Record (b1). File format is given in Appendix B.1.

Record (b1), File Name if Disk Storage Specified for Computed Responses

Read only if OUTPPR = OUTPPR in Record (b)
PPFILE (columns 1 - 30)

PPFILE — The disk file name for storing computed motions and loads for post-processing (maximum 30 characters). Appendix B.1 gives the format of the post-processing file.

Record (c), Additional Control Variables
LOADFLAG, RAWFLAG (2 character strings)

LOADFLAG Controls computations of sea loads. The two possible inputs are:

NOLOAD	No sea load computations.
LOAD	Sea load computations.

RAWFLAG Controls computations of added resistance in waves. The two possible inputs are:

NORAW	No added resistance computations.
RAW	Added resistance computations.

Record (d), Wave Frequencies for Response Calculations
WVFREQMIN, WVFREQMAX, DWVFREQ (3 reals)

WVFREQMIN Lowest wave frequency for ship motion calculations (rad/s).

WVFREQMAX Highest wave frequency for ship motion calculations (rad/s).

DWVFREQ Increment in wave frequency between WVFREQMIN and WVFREQMAX (rad/s). Due to storage considerations, DWVFREQ should be set such that DWVFREQ $\geq$ (WVFREQMAX $-$ WVFREQMIN)/39.

Note: If any of WVFREQMIN, WVFREQMAX, or DWVFREQ equals 0, then the program sets WVFREQMIN to $2/T_{C-max}$ and WVFREQMAX to $20/T_{C-min}$, where T_{C-min} and T_{C-max} are the minimum and maximum characteristic wave periods for irregular seaways. If the run is for regular waves only (SPECTRUM = REGULAR in Record (g)), the default values for WVFREQMIN and WVFREQMAX are 0.2 rad/s and 2.0 rad/s, respectively.

Record (e), Control Variables for Hydrodynamic Coefficients
SAVEHY, HYMETHOD, HYEND, LOWHVCOR (4 character strings)

SAVEHY Controls disk file storage of two-dimensional section potentials, added mass and damping. The three possible inputs are:

NOSAVEHY	Disk storage is not used.
WRITEHY	The hull sectional potentials, added mass and damping which are computed in the program are stored in a sequential disk file for future use. The name of the disk file must be specified in Record (e1).
READHY	The hull sectional potentials, added mass and damping for the ship are read from a sequential disk file which has already been created through a previous execution of the program. The disk file name must be specified in Record (e1).

HYMETHOD Control variable governing the computational method for the hull sectional properties. The two possible inputs are:

BOUND2D	Hull sectional properties are computed using section offsets and the boundary element method.
CONFORMAL	Hull sectional properties are computed using general section data (beam, draft, area coefficient) and the conformal mapping method. Long wavelength approximations are made in computing exciting forces. This method involves less computation time.

HYEND Control variable for end-effect hydrodynamic terms. The five possible inputs are:

NOHYEND	Hydrodynamic end-effect terms not included.
SWAYYAW	Hydrodynamic end-effect terms included for sway and yaw.
LAT	Hydrodynamic end-effect terms included for sway, roll, and yaw.
LONG	Hydrodynamic end-effect terms included for heave and pitch.
LATLONG	Hydrodynamic end-effect terms included for sway, heave, roll, pitch and yaw.

LOWHVCOR Control variable for sectional heave coefficients at low encounter frequencies. The two possible inputs are:

NOHVCOR	No low encounter frequency corrections.
HVCOR	Heave coefficients corrected at low encounter frequencies.

Notes: The conformal mapping method gives efficient and reliable results for sections which can be represented by Lewis forms. The boundary element method should be used when a section cannot be adequately represented by a Lewis form or when roll motions are important.

For consistency with between motion and load computations, HYEND should be set to LATLONG.

Record (e1), File Name for Reading or Writing Potentials, Added Mass and Damping

Read only if SAVEHY = WRITEHY or READHY in Record (e).
HYFILE (columns 1 - 30)

HYFILE The disk file name for hull sectional potentials, added mass and damping coefficients (maximum 30 characters).

Record (f), Encounter Frequencies for Added Mass and Damping Calculations
ENFREQMIN, ENFREQMAX, DENFREQ (3 reals)

ENFREQMIN — Lowest encounter frequency for which the hull sectional potentials, added mass and damping are calculated (rad/s).

ENFREQMAX — Highest encounter frequency for which the hull sectional potentials, added mass and damping are calculated (rad/s).

DENFREQ — Increment in encounter frequency between ENFREQMIN and ENFREQMAX for which the hull sectional properties are calculated (rad/s). Due to storage considerations, DENFREQ should be set such that DENFREQ $\geq$ (ENFREQMAX $-$ ENFREQMIN)/39.

Note: If input values for any of ENFREQMIN, ENFREQMAX, or DENFREQ are equal to zero, then SHIPMO7 sets ENFREQMIN to $\sqrt{g/L}$ and ENFREQMAX to $15\sqrt{g/L}$, with appropriate rounding. DENFREQ is also set to an appropriate value.

Record (g), Wave Spectrum
SPECTRUM (1 character string)

SPECTRUM — Specifies the seaway spectrum to be used for motion calculations in irregular seaways. The nine possible inputs are:

REGULAR	Regular waves only.
QUADRATIC	Quadratic regression spectrum.
BRETSCHNEIDER	Bretschneider two parameter spectrum.
JONSWAP	JONSWAP spectrum.
OCHIHUBBLE	Ochi and Hubble six parameter uni-directional spectrum.
INPUTUNI	Input uni-directional spectrum.
TENPARAMETER	Ten parameter directional spectrum.
ODGPHINDCAST	ODGP hindcast directional spectrum.
INPUTDIR	Input directional spectrum.

Record (g1), Number of Sea Directions and Short-Crested Analysis Spreading Angle
Read only if SPECTRUM = REGULAR, QUADRATIC, BRETSCHNEIDER, JONSWAP, OCHIHUBBLE or INPUTUNI in Record (g).
NSEADIR, SPREADANG (1 integer, 1 real)

NSEADIR — Number of principal sea directions to be considered with respect to ship heading (maximum of 36). If NSEADIR = 0, default headings from 0 to 180 degrees in 15 degree increments and a spreading angle of 90 degrees are used.

SPREADANG — The spreading angle (degrees) to be used in a short-crested sea spectrum analysis. If SPREADANG $\leq$ 0.0 and NSEADIR $>$ 0, no short-crested analysis is carried out.

Record (g2), Principal Sea Directions

Read only if SPECTRUM = REGULAR, QUADRATIC, BRETSCHEIDER, JONSWAP, OCHIHUBBLE, or INPUTUNI in Record (g) and NSEADIR > 0 in Record (g1).
SEADIR(I) (NSEADIR reals)

SEADIR(I) The principal sea directions to be considered relative to the ship velocity vector (degrees). There must be NSEADIR values.

Notes: If SPREADANG > 0.0 and NSEADIR > 0 in Record (g1), a sufficient range of sea directions must be given for short-crested calculations. For all seakeeping positions on the centreline (YPOS(I) = 0.0 for all I in Record (o2)), SEADIR must cover the range 0 - 180 degrees. If any seakeeping position is off centreline, SEADIR must cover the range from 0 to a minimum of 315.0 degrees. A sea direction value of 180 degrees must be included in array SEADIR for short-crested calculations.

If SPREADANG > 0.0 and NSEADIR > 0 in Record (g1), SEADIR values must be given in ascending order, with a maximum increment of 45.0 degrees between any 2 values.

Record (g3), Number of Seaways

NSEAWAY (1 integer)

NSEAWAY Number of seaways for which motions are to be computed (maximum 10).

Note: If regular waves, an input spectrum (unidirectional or directional) or a hindcast spectrum is used (SPECTRUM = REGULAR, INPUTUNI, ODGPHINDCAST, or INPUTDIR) NSEAWAY must be set equal to 1.

Record (h1), Wave Steepness in Regular Waves

Read only if SPECTRUM = REGULAR in Record (g).
WAVESTEEP (1 real)

WAVESTEEP Wave steepness H/λ. The maximum allowable value for wave steepness is 0.14 ($\approx$1/7). The relationship between wave slope ka and wave steepness H/λ is as follows:

$$ka = \pi H/\lambda \tag{A.1}$$

Record (h2), Significant Wave Height and Characteristic Period

Read only if SPECTRUM = QUADRATIC or BRETSCHEIDER in Record (g)
HSW(I), TSW(I) (NSEAWAY records, 2 reals/record)

HSW(I) Significant wave height of seaway I (ft or m).

TSW(I) Characteristic wave period (sec). For a BRETSCHNEIDER spectrum, TSW(I) is the peak period of seaway I. For a QUADRATIC spectrum, TSW(I) is the energy-averaged period of seaway I.

Record (h3), JONSWAP Significant Wave Height, Peak Period and Peak Enchancement Factor

Read only if SPECTRUM = JONSWAP in Record (g)
HSW(I), TSW(I) PEAKENSW(I) (NSEAWAY records, 3 reals/record)

HSW(I) Significant wave height of seaway I (ft or m).

TSW(I) Peak wave period (sec).

PEAKENSW(I) Peak enhancement factor. To match a two-parameter JONSWAP spectrum, the peak enhancement factor should be set to 3.3.

Record (h4a), File Name for Unidirectional Spectral Data from Disk File

Read only if SPECTRUM = INPUTUNI in Record (g)
SPUNIFILE (columns 1-30)

SPUNIFILE The disk file name for wave sea spectral data (maximum 30 characters). The spectral data file must contain 2 × NFREQSPUNI entries in the following order:

$$\omega_1, S(\omega_1), \omega_2, S(\omega_2), \omega_3, S(\omega_3), ..., \omega_N, S(\omega_N)$$

where $S(\omega_i)$ is the spectral density at frequency ω_i. A sample input file is given in Appendix A.3.

Record (h4b), Units for Unidirectional Spectral Data from Disk File

Read only if SPECTRUM = INPUTUNI in Record (g)
SPUNISYS (1 character string)

SPUNISYS System of units for spectral density. The two possible inputs are:

BRITISH British units

METRIC Metric units

The units of spectral density ($ft^2/(rad/s)$ or $m^2/(rad/s)$) may be chosen independently of the value INSYS specified in Record (b).

Record (h4c), Number of Wave Frequencies in Input Unidirectional Spectrum

Read only if SPECTRUM = INPUTUNI in Record (g)
NFREQSPUNI (1 Integer)

NFREQSPUNI Number of wave frequencies (maximum 101) in input unidirectional spectrum file SPUNIFILE.

Record (h5), Ochi and Hubble 6 Parameter Unidirectional Spectrum

Read only if SPECTRUM = OCHIHUBBLE in Record (g)
ZETA1(I), OMEGA1(I), LAMB1(I), ZETA2(I), OMEGA2(I), LAMB2(I) (NSEAWAY records, 6 reals/record)

ZETA1(I) Significant wave height of swell component (ft or m).

OMEGA1(I) Peak frequency of swell component (rad/s).

LAMB1(I) Spectral shape parameter of swell component.

ZETA2(I) Significant wave height of sea component (ft or m).

OMEGA2(I) Peak frequency of sea component (rad/s).

LAMB2(I) Spectral shape parameter of sea component.

Record (h6), 10 Parameter Directional Spectrum

Read only if SPECTRUM = TENPARAMETER in Record (g)
ZETA1(I), OMEGA1(I), LAMB1(I), KAPA1(I), EXPP1(I), ZETA2(I), OMEGA2(I), LAMB2(I), KAPA2(I), EXPP2(I) (NSEAWAY records, 10 reals/record)

ZETA1(I) Significant wave height of swell component (ft or m).

OMEGA1(I) Peak frequency of swell component (rad/s).

LAMB1(I) Spectral shape parameter of swell component.

KAPA1(I) Mean compass direction (from) of swell component (degrees).

EXPP1(I) Directional spreading parameter of swell component.

ZETA2(I) Significant wave height of sea component (ft or m).

OMEGA2(I) Peak frequency of sea component (rad/s).

LAMB2(I) Spectral shape parameter of sea component.

KAPA2(I) Mean compass direction (from) of sea component (degrees).

EXPP2(I) Directional spreading parameter of sea component.

Record (h7), Hindcast Spectrum File Name

Read only if SPECTRUM = ODGPHINDCAST in Record (g)
HCFILE (columns 1 - 30)

HCFILE The disk file name from which hindcast data are read (maximum 30 characters). The format of hindcast spectral data files is described in Appendix A.4, and a sample file is given in Appendix A.5. The units for this input file are metric, regardless of the values chosen for INSYS and OUTSYS in Record (b).

Record (h8), Input Directional Spectrum File Name

Read only if SPECTRUM = INPUTDIR in Record (g)

SPDIRFILE (columns 1 - 30)

SPDIRFILE — The disk file name from which the input directional spectrum is read (maximum 30 characters). The format of the input directional spectrum files is described in Appendix A.6. The units for this input file are metric, regardless of the values chosen for INSYS and OUTSYS in Record (b).

Record (i), Ship Speeds

NSPEED, (SPDKNOT(I), I = 1, NSPEED) (1 integer, NSPEED reals)

NSPEED — Number of ship speeds (maximum 10).

SPDKNOT(I) — Array of ship speeds (knots).

Record (j), Basic Ship Data

SHIPLEN, KG, PITCHRG (3 reals)

SHIPLEN — Length between perpendiculars (ft or m).

KG — Height of CG (ft or m) above the baseline.

PITCHRG — Pitch radius of gyration in air (ft or m). A typical value is $0.25L$.

Record (k), Control Variables for Computation of Metacentric Height and Roll Radius of Gyration

GMFLAG, ROLLRGDEF (2 character strings)

GMFLAG — Control variable for determination of metacentric height GM. The two possible inputs are:

- GMCOMP — $\overline{GM}$ and roll stiffness are computed based on hydrostatics and input $\overline{KG}$.
- GMINPUT — A user input value of $\overline{GM}$ is read. Roll stiffness is based on this value rather than the CG location.

ROLLRGDEF — Control variable for definition of roll moment of inertia. The three possible inputs are:

- WETROLLNF — Roll natural frequency in water (rad/s).
- DRYROLLRG — Roll radius of gyration in air.
- WETROLLRG — Roll radius of gyration in water.

Note: A user input metacentric height should be used if free-surface effects are to be modelled.

Record (k1), User Input Metacentric Height
Read only if GMFLAG = GMINPUT in Record (k)
GMUSER (1 real)

GMUSER — User input value for metacentric height $\overline{GM}$ (ft or m).

Record (k2), Roll Natural Frequency
Read only if ROLLRGDEF = WETROLLNF in Record (k)
ROLLNF (1 real)

ROLLNF — Roll natural frequency in water (rad/s) for computing roll moment of inertia. ($I_{44} = K_{44}/ROLLNF^2 - A_{44}$).

Record (k3), Dry Roll Radius of Gyration
Read only if ROLLRGDEF = DRYROLLRG in Record (k)
ROLLRG (1 real)

ROLLRG — Roll radius of gyration in air (ft or m) ($I_{44} = \triangle \times ROLLRG^2$). For a small warship in water, ROLLRG typically lies between $0.32B$ and $0.36B$ (approximately 0.9 WETROLLRG), where B is ship beam.

Record (k4), Wet Roll Radius of Gyration
Read only if ROLLRGDEF = WETROLLRG in Record (k)
WETROLLRG (1 real)

WETROLLRG — Roll radius of gyration in water (ft or m) ($I_{44} = \triangle \times WETROLLRG^2 - A_{44}$). For a small warship, WETROLLRG typically lies between $0.35B$ and $0.40B$, where B is ship beam.

Record (l), Control Variable for Hull Definition
HULLDEF (1 character string)

HULLDEF — Control variable for hull definition. The two possible inputs are:

- OFFSETS — The hull is defined by sectional offsets going from the keel to the deck edge.
- BEAMDRAFT — The hull is defined by sectional values for beam, draft, and area coefficient.

Record (l1), Station Definition and Scaling Factors
NST, NSTOFF, BEAMSF, DRAFTSF (2 integers, 2 reals)

NST — Total number of equally spaced stations into which the ship hull has been divided for representation (maximum 21). Set to 21 to have stations numbered from 0 to 20.

NSTOFF — The number of stations for which offsets or beam, draft and area coefficient are input. NSTOFF can be less than NST if the ship has forward or aftermost sections of zero area.

BEAMSF — A beam-wise scaling factor, applied to the horizontal offsets, YAUSER, given in Record (13a), or to the station beam given in Record (14). A default value of 1.0 is assigned if BEAMSF ≤ 0.

DRAFTSF — A draft-wise scaling factor, applied to the vertical offsets, ZAUSERBL, given in Record (13b), or to the station draft given in Record (14). A default value of 1.0 is assigned if DRAFTSF ≤ 0.

Notes: NSTOFF should be sufficiently large to adequately describe the hull. For each of the NSTOFF stations, there must be one Record (12) followed by either one each of Records (13), (13a) and (13b), or one Record (14).

BEAMSF and DRAFTSF allow SHIPMO runs of breadth and draft variations without altering offset files.

Record (12), Station Number

XST(I) (1 real)

XST(I) — Station number ($0 \leq \text{XST} \leq \text{NST} - 1$). Station 0 is at the forward perpendicular, and station NST $- 1$ is at the after perpendicular.

Record (13), Number of Offsets at Station XST(I)

Read only if HULLDEF = OFFSETS in Record (1)
NOFFUSER(I) (1 integer)

NOFFUSER(I) — Number of offsets to follow in Records (13a) and (13b) (maximum 30).

Record (13a), Horizontal Offsets at Station XST(I)

Read only if HULLDEF = OFFSETS in Record (1).
YAUSER(I,J) (NOFFUSER(I) reals)

YAUSER(I,J) — NOFFUSER(I) horizontal offsets of station I (ft or m). The first offset point of each station must have a YAUSER value of 0.0.

Record (13b), Vertical Offsets at Station XST(I)

Read only if HULLDEF = OFFSETS in Record (1).
ZAUSERBL(I,J) (NOFFUSER(I) reals)

ZAUSERBL(I,J) — NOFFUSER(I) vertical offsets of station I (ft or m). Values are given as heights above the hull baseline.

Note: If input offsets are given, then offsets should extend from the keel to the deck edge or back to the centerline for a submerged section. See Figure 8 for an illustration of offset points extending to the deck edge.

Record (l4), Beam, Draft and Area Coefficient at Station XST(I)

Read only if HULLDEF = BEAMDRAFT in Record (l).
BEAM(I), DRAFT(I), ACOEF(I) (3 reals)

BEAM(I) Beam at station I (ft or m).

DRAFT(I) Draft at station I (ft or m).

ACOEF(I) Area coefficient at station I.

Note: Offsets are generated internally using a Lewis form. Figure 4 shows valid ranges of parameters for Lewis forms.

Record (m), Control Variable for Load Waterline Calculation

TRIMDEF (1 character string)

TRIMDEF Indicates the method used to specify the loading conditions (i.e. baseline depth and angle). The two possible inputs are:

DRAFT	Input midship draft and trim by stern (Record (m1)).
DISP	Input displacement and LCG location (Record (m2)).

Note: If the hull geometry is input as sectional coefficients (HULLDEF = BEAMDRAFT in Record (l)), then TRIMDEF must be set to DRAFT.

Record (m1), Draft at Midships and Trim by the Stern

Read only if TRIMDEF = DRAFT in Record (m).
DRAFTMID, TRIMST (2 reals)

DRAFTMID Draft at midships (ft or m).

TRIMST Trim by the stern (positive for stern down) relative to bow (ft or m).

Note: Figure 7 illustrates draft at midships and trim by the stern.

Record (m2), Displacement and Longitudinal Centre of Gravity

Read only if TRIMDEF = DISP in Record (m).
DISPUSER, LCGFPUSER (2 reals)

DISPUSER Ship displacement (tons or tonnes).

LCGFPUSER Distance from the forward perpendicular to the LCG (ft or m).

Record (n), Number of Stations for Load Calculations

Read only if LOADFLAG = LOAD in Record (c).
NSTLOAD (1 integer)

NSTLOAD Number of stations for load calculations (maximum 21).

Record (n1), Stations for Load Calculations

Read only if LOADFLAG = LOAD in Record (c).
XSTLOAD(I) (NSTLOAD reals)

XSTLOAD(I) Station for load calculation ($0 \leq$ XSTLOAD(I) $\leq$ NST - 1). Loads can be computed between integer station numbers (e.g. XSTLOAD(I) could equal 2.3).

Record (n2), Sectional Weight or Mass

Read only if LOADFLAG = LOAD in Record (c).
SECTTN(I) (NST reals)

SECTTN(I) Weight (tons) or mass (tonnes) of station I. For station 0, SECTN is the weight or mass between the FP and station 0.5. For intermediate stations, SECTN is the weight or mass between mid-station points (e.g. SECTN for station 1 is the weight or mass between stations 0.5 and 1.5). For the aft station NST-1, SECTN is the weight or mass between station NST-1.5 and the AP (e.g. the weight or mass between stations 19.5 and 20 if NST = 21).

Record (n3), Sectional Height of Center of Gravity above Baseline

Read only if LOADFLAG = LOAD in Record (c).
SECTKG(I) (NST reals)

SECTKG(I) Vertical distance (ft or m) from baseline to center of gravity at station I. If $\overline{KG}$ values are set to zero for all stations, the bow overhang (Record (n5)), and the stern overhang (Record (n6)), then SHIPMO sets all sectional $\overline{KG}$ values to the ship KG given in Record (j).

Record (n4), Sectional Roll Radius of Gyration

Read only if LOADFLAG = LOAD in Record (c).
SECTRRG(I) (NST reals)

SECTRRG(I) Sectional dry roll radius of gyration (ft or m) relative to sectional center of gravity. If roll gyradius values are set to zero for all stations, the bow overhang (Record (n5)), and the stern overhang (Record (n6)), then SHIPMO estimates values for sectional gyradii such that the ship gyradius determined by input Records (k) to (k4) is satisfied.

Record (n5), Bow Overhang Mass Distribution

Read only if LOADFLAG = LOAD in Record (c).
BOWTN, BOWKG, BOWRRG, BOWCGFP, BOWPRG (5 reals)

BOWTN Weight (tons) or mass (tonnes) of mass overhanging forward perpendicular.

BOWKG Vertical distance from baseline to center of gravity of bow overhang (ft or m).

BOWRRG Bow overhang dry roll radius of gyration (ft or m) relative to bow overhang center of gravity.

BOWCGFP — Horizontal distance (ft or m) from forward perpendicular to center of gravity of bow overhang. BOWCGFP must be positive.

BOWPRG — Bow overhang pitch radius of gyration (ft or m) relative to bow overhang center of gravity.

Record (n6), Stern Overhang Mass Distribution

Read only if LOADFLAG = LOAD in Record (c).
STERNTN, STERNKG, STERNRRG, STERNCGAP, STERNPRG (5 reals)

STERNTN — Weight (tons) or mass (tonnes) of mass overhanging aft perpendicular.

STERNKG — Vertical distance from baseline to center of gravity of stern overhang (ft or m).

STERNRRG — Stern overhang dry roll radius of gyration (ft or m) relative to stern overhang center of gravity.

STERNCGAP — Horizontal distance (ft or m) from aft perpendicular to center of gravity of stern overhang. STERNCGAP must be positive.

STERNPRG — Stern overhang pitch radius of gyration (ft or m) relative to stern overhang center of gravity.

Record (o), Positions for Seakeeping Calculations and Slamming Parameters

NPOS, SLAMHOUR, SLAMEX, (1 integer, 2 reals)

NPOS — Number of positions for irregular seas seakeeping calculations (maximum 10).

SLAMHOUR — Time period (hours) for which number of slams, slamming pressures and slamming forces are computed for the stations specified in Records (o1) to (o5). If SLAMHOUR = 0.0, a default value of 20 hours is used.

SLAMEX — Exceedence parameter for calculating extreme slamming pressure for design. If SLAMEX = 0.0, a default value of 0.01 is used.

Note: Records (o1) and (o2) are required for each of the NPOS positions.

Record (o1), Labels and Control Variables for Seakeeping Positions

Read only if NPOS $\geq$ 1 in Record (o)
POSLABEL(I), RELMOCALC(I), MIIFLAG(I) (NPOS records of 3 character strings)

POSLABEL(I) — Description of seakeeping position I (20 character maximum).

RELMOCALC(I) — Variable describing relative vertical motion computations at seakeeping position I. The five possible inputs are:

- NOSLAM — No slamming or deck wetness calculations are done for station I. Records (o3) to (o5) are not required.

SLAMFORM	Slamming calculations are done at station I using a form factor and effective pressure width given in Record (o3). Deck wetness calculations are also performed.
SLAMOFFSET	Slamming calculations are done for station I using offsets given in Records (o4a) to (o4c). Deck wetness calculations are also performed.
SLAMWEDGE	Slamming calculations are performed at station I using a wedge approach. The wedge angle and height are given in Record (o5).
DECKWET	Deck wetness calculations are done for station I. Records (o3) to (o5) are not required.
EMERGE	Emergence calculations (typically for a propeller or sonar dome) are performed at station I. No Records (o3) to (o5) are required.

MIIFLAG(I) Control variable for MII calculations at position I.

NOMII	No MII calculations are performed at position I. No Record (o6) is required.
MII	MII calculations are performed at position I. Record (o6) is required.

Note: For each seakeeping position, one Record (o1) and one Record (o2) are required. An additional record is required if RELMOCALC(I) equals SLAMFORM, SLAMOFFSET, or SLAMWEDGE as follows:

SLAMFORM	Record (o3),
SLAMOFFSET	Records (o4a), (o4b), and (o4c),
SLAMWEDGE	Record (o5).

In addition, an MII data record is required if MIIFLAG equals MII.

Record (o2), Geometry for Seakeeping Calculations

Read only if NPOS $\geq$ 1 in Record (o).

XSTPOS(I), YPOS(I), ZPOSBL(I), DECKHBL(I) (NPOS records of 4 reals)

XSTPOS(I) Station number of position I where calculations are to be done ($0 \leq$ XSTPOS $\leq$ NST $-$ 1).

YPOS(I) Horizontal coordinate (y-coordinate, + port) of position I relative to the centreline (ft or m).

ZPOSBL(I) Vertical coordinate (z-coordinate) of position I relative to the baseline (ft or m).

DECKHBL(I) Distance from the baseline to the deck edge at position I (ft or m). If the resulting freeboard is negative, deck wetness computations are omitted.

Record (o3), Slamming Form Factor and Effective Force Width

Read only if RELMOCALC = SLAMFORM in Record (o1).
SLFORM(I), SLWIDTH(I) (2 reals)

SLFORM(I) Slamming form factor.

SLWIDTH(I) Effective slamming force width (ft or m).

Record (o4a), Number of Slamming Offsets and Upper Limit for Slam Pressure

Read only if RELMOCALC = SLAMOFFSET in Record (o1).
NSLOFF(I), ZSLUPBL(I) (1 integer, 1 real)

NSLOFF(I) Number of offsets input for station I in performing slamming calculations. Maximum value for NSLOFF(I) is 11.

ZSLUPBL(I) Elevation above baseline at which slamming pressure goes to 0. ZSUPBL(I) is typically assumed to be at a height of $0.1T_x$ above the section bottom, where T_x is a nominal sectional draft.

Record (o4b), Horizontal Offsets for Slamming

Read only if RELMOCALC = SLAMOFFSET in Record (o1).
YSLOFF(I,J) (NSLOFF(I) reals)

YSLOFF(I,J) NSLOFF(I) horizontal offsets beginning at the keel centerline and going to at least elevation ZSLUPBL(I) above the baseline. See Figure 12.

Record (o4c), Vertical Offsets for Slamming

Read only if RELMOCALC = SLAMOFFSET in Record (o1).
ZSLOFF(I,J) (NSLOFF(I) reals)

ZSLOFFBL(I,J) NSLOFF(I) vertical offsets relative to the baseline beginning at the keel centerline and going to at least elevation ZSLUPBL(I) above the baseline. See Figure 12.

Record (o5), Geometry for Wedge Slamming Calculations

Read only if RELMOCALC = SLAMWEDGE in Record (o1).
DEADR(I), SLHEIGHT (2 reals)

DEADR(I) Deadrise angle at position I (degrees). For correct slamming force calculations, DEADR(I) > 0 degrees. If DEADR(I) < 5 degrees, the internal calculation of form factor may not be accurate. In this case, it is recommended that the form factor be input using Record (o3), or that offsets be input using Records (o4a) to (o4c).

SLHEIGHT(I) Height above keel at which slamming pressure goes to zero (typically taken as $0.1T_x$).

Record (o6), Data for MII Calculations
Read only if MIIFLAG = MII in Record (o1).
TCLAT(I), TCLONG(I), TIMEOP(I) (3 reals)

TCLAT(I) Lateral tipping or sliding coefficient at position I. If TCLAT < 0, a default value of 0.25 is used.

TCLONG(I) Longitudinal tipping or sliding coefficient at position I. If TCLONG < 0, a default value of 0.17 is used.

TIMEOP(I) Time of operation at position I (s). If TIMEOP < 0, a default value of 60 seconds is used.

Note: For sliding calculations, the user should set TCLAT(I) and TCLONG(I) equal to the static coefficient of friction.

Record (p), Number of Bilge Keel Pairs
NBKPAIR (1 integer)

NBKPAIR Number of bilge keel pairs (maximum value = 5).

Record (p1), First and Last Stations Spanned by Bilge Keel
Read only if NBKPAIR ≥ 1 in Record (p).
IFIRSTBK(I), ILASTBK(I) (NBKPAIR records, 2 integers)

IFIRSTBK(I) First station spanned by bilge keel I. A station is considered to spanned by a bilge keel if the bilge keel lies within half a station.

ILASTBK(I) Last station spanned by bilge keel I.

Record (p2), Bilge Keel Dimensions
Read only if NBKPAIR ≥ 1 in Record (p).
XSTBKFORE(I,J), XSTBKAFT(I,J), YBK(I,J), ZBKBL(I,J), BBK(I,J) (5 reals/record)

XSTBKFORE(I,J) Forward station location of bilge keel portion.

XSTBKAFT(I,J) Aft station location of bilge keel portion.

YBK(I,J) Horizontal bilge keel offset (ft or m).

ZBKBL(I,J) Vertical bilge keel offset (ft or m) relative to hull baseline.

BBK(I,J) Bilge keel breadth (ft or m).

Note: One Record (p2) is required for each station spanned by bilge keel I. That is, following each Record (p1), there must be (ILASTBK(I) $-$ IFIRSTBK(I) $+ 1$) Records (p2). See Figures 17 and 18 for clarification of bilge keel inputs.

Record (q), Skeg Data
XSTAFTSKEG, BSKEG, ELSKEG (3 reals)

XSTAFTSKEG — Station number ($0 \leq$ XSTSKEG $\leq$ NST $- 1$) of aftmost point where skeg meets hull (see Figure 19).

BSKEG — Skeg breadth (ft or m).

ELSKEG — Skeg length (ft or m).

Record (r), Rudder Data
XSTRUD, YRTRUD, ZRTRUDBL, SPANRUD, RCRUD, TCRUD, CLA0RUD, ISLIPRUD (7 reals, 1 integer)

XSTRUD — Station at which rudder is located ($0 \leq$ XSTRUD $\leq$ NST $- 1$).

YRTRUD — Lateral coordinate (ft or m) of root of rudder. If YRTRUD = 0.0, the ship is assumed to have a single rudder. If the rudder stock offset distance is positive (YRTRUD $>$ 0.0), it is assumed that there are twin rudders, each with the specified span and chord.

ZRTRUDBL — Vertical coordinate of rudder root (ft or m) relative to hull baseline.

SPANRUD — Span of rudder (ft or m).

RCRUD — Root chord of rudder (ft or m).

TCRUD — Tip chord of rudder (ft or m).

CLA0RUD — Lift curve slope of rudder root (rad^{-1}) before boundary layer correction. If CLA0RUD is unknown, input zero and the program will calculate a value.

ISLIPRUD — Integer flag indicating whether rudder is in propeller slipstream:

- ISLIPRUD = 0 Rudder is not in propeller slipstream. Boundary layer correction will be applied.
- ISLIPRUD = 1 Rudder is in propeller slipstream. No boundary layer correction.

Record (r1), Rudder Roll Gains, Natural Frequency and Damping
RAGNRUD, RVGNRUD, RGNRUD, FREQRUD, DAMPRUD, FREQLRUD, FREQHRUD (7 reals)

RAGNRUD — Rudder roll acceleration gain (sec^2).

RVGNRUD — Rudder roll velocity gain (sec).

RGNRUD — Rudder roll gain.

FREQRUD — Rudder control system natural frequency (rad/s).

DAMPRUD	Rudder control system damping ratio.
FREQLRUD	Low frequency cut-off for rudder roll stabilizer (rad/s).
FREQHRUD	High frequency cut-off for rudder roll stabilizer (rad/s).
Note:	If modelling of the steering system is not required, all parameters in Record (r1) should be set to zero.

Record (r2), Rudder Yaw Gains
YAGNRUD, YVGNRUD, YGNRUD (3 reals)

YAGNRUD	Rudder yaw acceleration gain (sec^2).
YVGNRUD	Rudder yaw velocity gain (sec).
YGNRUD	Rudder yaw gain.
Note:	If modelling of the steering system is not required, all parameters in Record (r2) should be set to zero.

Record (s), Number of Stationary Foil Pairs
NFOILPAIR (1 integer)

NFOILPAIR	Number of pairs of stationary foils.

Record (s1), Stationary Foil Data
Read only if NFOILPAIR ≥ 1 in Record (s)
XSTFOIL(I), YRTFOIL(I), ZRTFOILBL(I), SPANFOIL(I), RCFOIL(I), TCFOIL(I), CLA0FOIL(I), DIANGFOIL(I) (NFOILPAIR records of 8 reals/record)

XSTFOIL(I)	Station at which foil I is located ($0 \leq$ XSTFOIL(I) $\leq$ NST $- 1$).
YRTFOIL(I)	Lateral coordinate of foil root I (ft or m).
ZRTFOILBL(I)	Vertical coordinate of root of foil I (ft or m) relative to hull baseline.
SPANFOIL(I)	Span of foil I (ft or m).
RCFOIL(I)	Root chord of foil I (ft or m).
TCFOIL(I)	Tip chord of foil I (ft or m).
CLA0FOIL(I)	Lift curve slope of foil I (rad^{-1}) before boundary layer correction. If the lift curve slope CLA0FOIL(I) is unknown, input zero and the program will calculate a value.
DIFOIL(I)	Dihedral angle of foil I relative to lateral axis (degrees).
Note:	See Figures 15 and 16 for foil inputs and example dihedral angles.

Record (t), Fin and Tank Roll Stabilization Control Variable
FINTANKSTAB (1 character string)

FINTANKSTAB Control variable for fin and tank stabilization. The three possible inputs are:

NOSTAB	No fin or tank stabilization.
FIN	Fin roll stabilization.
UTUBETANK	U-tube tank roll stabilization.

Record (u), Number of Fin Pairs
Read only if FINTANKSTAB = FIN in Record (t)
NFINPAIR (1 integer)

NFINPAIR Number of fin pairs.

Record (u1), Stabilization Fin Data
Read only if FINTANKSTAB = FIN in Record (t) and NFINPAIR ≥ 1 in Record (u)
XSTFIN(I), YRTFIN(I), ZFINBL(I), SPANFIN(I), RCFIN(I), TCFIN(I), CLA0FIN(I), DIFIN(I) (NFINPAIR records of 8 reals/record)

XSTFIN(I) Station at which fin I is located ($0 \leq$ XSTFIN(I) $\leq$ NST $- 1$).

YRTFIN(I) Lateral coordinate of root of fin I (ft or m).

ZFINBL(I) Vertical coordinate of root of fin I (ft or m) relative to hull baseline.

SPANFIN(I) Span of fin I (ft or m).

RCFIN(I) Root chord of fin I (ft or m).

TCFIN(I) Tip chord of fin I (ft or m).

CLA0FIN(I) Lift curve slope of fin I (rad^{-1}) before boundary layer correction. If CLA0FIN(I) is unknown, input zero and the program will calculate a value.

DIFIN(I) Dihedral angle of fin I relative to lateral axis (degrees).

Record (u2), Fin Roll Gains, Natural Frequency and Damping
Read only if FINTANKSTAB = FIN in Record (t) and NFINPAIR ≥ 1 in Record (u).
RAGNFIN, RVGNFIN, RGNFIN, FREQFIN, DAMPFIN, FREQHFIN (6 reals)

RAGNFIN Fin roll acceleration gain (sec^2).

RVGNFIN Fin roll velocity gain (sec).

RGNFIN Fin roll gain.

FREQFIN Fin control system natural frequency (rad/s).

DAMPFIN Fin control system damping ratio.

FREQHFIN High frequency cut-off for fin roll stabilizer (rad/s).

Record (v), U-Tube Roll Stabilization Tank Data

Read only if FINTANKSTAB = UTUBETANK in Record (t)
TANKLEN, WDTANK, W1TANK, DPTANK, ALTANK, HDTANK, ZTANKBL, XSTTANK, SGTANK, VSTANK, VSOTANK, WBTANK (12 reals)

TANKLEN	Longitudinal length of anti-rolling tank (ft or m).
WDTANK	Width of tank connecting duct (ft or m).
W1TANK	Bottom width of tank vertical leg (ft or m).
DPTANK	Average fluid depth in tank vertical leg (ft or m).
ALTANK	Inclination of outside wall of tank vertical leg (degrees).
HDTANK	Height of tank connecting duct (ft or m).
ZTANKBL	Height above baseline of bottom of tank connecting duct (ft or m).
XSTTANK	Station number of tank location ($0 \leq$ XSTTANK $\leq$ NST $- 1$).
SGTANK	Specific gravity of tank fluid.
RESISTBTANK	Tank valve resistance coefficient for frequencies $\omega_e >$ BFREQTANK, the tank break frequency.
RESIST0TANK	Tank valve resistance coefficient for $\omega_e = 0$. RESIST0TANK should be set to 0.0 for a pure passive tank.
BFREQTANK	Break frequency (rad/s). BFREQTANK should be set to 0.0 for a pure passive tank.

Note: Tank inputs are illustrated in Figure 20.

A.2 Sample Input File

```
SHIPMO7 Example - CPF
METRIC METRIC SALT BOWSPEEDCOR BOWSWELLCOR MODAMP OUTPPR <----- Control flags
cpfexamp.ppr                              <----- Post-processing file name
LOAD   RAW                                <----- Additional computation flags
0.2 2.0 0.1                               <----- Wave frequencies
WRITEHY  BOUND2D  LATLONG  HVCOR          <----- Hydrodynamic options
cpfexamp.hy                               <----- Hydrodynamic coefficient file
0.2 6.0 0.2                               <----- Encounter frequencies
BRETSCHNEIDER                             <----- Wave spectrum
7 0.0                <----- # of sea directions, spread angle
0 30 60 90 120 150 180                    <----- Sea direction(s) (headings)
1               <----- Number of seaways
3.25 9.7                                  <----- Wave height, period
1  18.0                                   <----- # of ship speeds, ship speeds
124.5 6.23 29.815                         <----- Ship length, KG, pitch gyradius
GMINPUT  WETROLLRG                        <----- GM and roll gyradius control flags
1.135                                     <----- GM
5.2                                       <----- Wet roll radius of gyration
OFFSETS                                   <----- Hull definition flag
21 21 0.001 0.001                         <----- # of stations, scaling factors
0                                         <----- Offset data
12
  0  110  318  579  897 1000 1281  1757  2000  2361  3000  3615
4630 5000 6000 7000 8000 8288 9000 10000 10431 11000 11911 12725
1
20
 0  290  515  735  974 1000 1255 1586 1975 2000 2424 2938 3000  3534  3892  4000  4231  4951  5000  5398
126 1000 2000 3000 4000 4100 5000 6000 7000 7060 8000 9000 9112 10000 10530 10680 11000 12000 12068 12621
2
21
0  721 1000 1166 1552 1930 2000 2334 2774 3000 3256 3785 4000 4376 5000  5077  5160  5711  6000  6328  6590
0 1000 1608 2000 3000 4000 4179 5000 6000 6481 7000 8000 8379 9000 9900 10000 10105 11000 11468 12000 12426
3
22
0 1000 1160 1837 2000 2390 2913 3000 3426 3932 4000 4437 4984 5000 5624 6000 6160  6294  6782  7000
7270  7338
0  800 1000 2000 2280 3000 4000 4168 5000 6000 6136 7000 8000 8027 9000 9518 9724 10000 11000 11447
12000 12140
4
21
0 1000 1665 2000 2588 3000 3306 3916 4000 4446 4930 5000 5404 5926 6000 6561 6848 7000  7073  7442  7764
0  473 1000 1324 2000 2551 3000 4000 4150 5000 6000 6149 7000 8000 8128 9000 9390 9802 10000 11000 11871
5
21
0 1000 2000 2268 3000 3470 4000 4273 4869 5000 5330 5731 6000 6137 6594 7000 7147 7214  7477  7773  7956
0  303  828 1000 1555 2000 2622 3000 4000 4262 5000 6000 6672 7000 8000 8753 9000 9109 10000 11000 11618
6
21
0 1000 2000 2971 3000 4000 4373 5000 5204 5702 6000 6057 6365 6688 7000 7047 7409 7435  7693  7951  8049
0  188  534 1000 1016 1679 2000 2701 3000 4000 4824 5000 6000 7000 7876 8000 8900 9000 10000 11000 11379
7
23
0 1000 2000 3000 3713 4000 4573 5000 5190 5979 6000 6360 6622 6856 6903 7000 7101 7364 7583 7632  7856
8080  8133
0  150  364  680 1000 1142 1500 1830 2000 3000 3040 4000 5000 6000 6200 6597 7000 8000 8783 9000 10000
11000 11240
8
22
0 1000 2000 3000 4000 4340 5000 5165 5754 6000 6493 6812 7000 7020 7208 7246 7396 7584 7772  7959
8147  8183
0  150  338  527  844 1000 1385 1500 2000 2261 3000 4000 4898 5000 6000 6200 7000 8000 9000 10000
11000 11191
```

```
9
20
0 1000 2000 3000 4000 4724 5000 6000 6122 6814 7000 7104 7267 7417 7567 7717 7867  8017  8167  8198
0  150  338  525  732 1000 1140 1878 2000 3000 3538 4000 5000 6000 7000 8000 9000 10000 11000 11146
10
20
0 1000 2000 3000 4000 4895 5000 6000 6348 6989 7000 7258 7398 7528 7658 7788 7918  8048  8178  8191
0  150  338  525  715 1000 1046 1668 2000 3000 3027 4000 5000 6000 7000 8000 9000 10000 11000 11101
11
20
0 1000 2000 3000 4000 4940 5000 6000 6416 7000 7043 7312 7446 7569 7693 7816 7940  8063  8186  8199
0  150  338  525  713 1000 1025 1611 2000 2899 3000 4000 5000 6000 7000 8000 9000 10000 11000 11100
12
20
0 1000 2000 3000 4000 4824 5000 6000 6348 7000 7006 7300 7446 7569 7693 7816 7940  8063  8187  8199
0  150  338  525  733 1000 1074 1674 2000 2987 3000 4000 5000 6000 7000 8000 9000 10000 11000 11100
13
21
0 1000 2000 3000 4000 4433 5000 5527 6000 6181 6895 7000 7225 7390 7519 7647 7776 7904  8033  8161  8174
0  150  358  589  859 1000 1225 1500 1836 2000 3000 3245 4000 5000 6000 7000 8000 9000 10000 11000 11102
14
22
0 1000 2000 3000 3437 4000 4896 5000 5777 6000 6673 6988 7000 7060 7260 7397 7533 7669 7806  7942
8079  8093
0  345  647  895 1000 1155 1500 1549 2000 2176 3000 3750 3789 4000 5000 6000 7000 8000 9000 10000
11000 11108
15
22
0 1000 1183 2000 3000 3085 4000 4787 5000 6000 6183 6668 6780 7000 7063 7221 7364 7508 7652  7796
7939  7956
0  897 1000 1281 1483 1500 1720 2000 2098 2793 3000 3750 4000 4707 5000 6000 7000 8000 9000 10000
11000 11118
16
22
  0  341  759 1000 1716 2000 3000 4000 5000 5376 6000 6216 6385 6811 7000 7012 7172 7309 7458  7606
7754  7774
517 1000 1500 1682 2000 2075 2260 2465 2803 3000 3494 3750 4000 5000 5918 6000 7000 8000 9000 10000
11000 11130
17
20
  0  178 1000 2000 3000 3293 4000 5000 5568 5892 6000 6512 6757 6911 7000 7065 7218  7372  7525  7548
1880 2000 2453 2750 2944 3000 3152 3461 3750 4000 4109 5000 6000 7000 7579 8000 9000 10000 11000 11146

18
20
  0  148 1000 2000 3000 4000 5000 5131 6000 6117 6460 6491 6618 6776 6879 6935 7000  7093  7252  7278
2970 3000 3153 3318 3488 3675 3945 4000 4677 5000 6000 6200 7000 8000 8650 9000 9411 10000 11000 11164

19
18
  0 1000 2000 3000 3871 4000 5000 5807 5913 6000 6125 6286 6447 6473 6608  6769  6930  6959
3670 3739 3811 3894 4000 4020 4286 5000 5220 5461 6000 7000 8000 8160 9000 10000 11000 11184
20
14
  0 2000 3500 5000 5434 5549 5630 5767 5924 6000 6081 6237  6394  6493
4630 4630 4630 4630 5000 5220 5500 6000 7000 7486 8000 9000 10000 10632
DISP                              <----- Control flag for load waterline
4731.8 64.553                      <----- Displacement, LCGFP
1                                  <----- Number of stations for load calcs
10.0         <----- Stations for load calcs
 25.69    79.04   123.18   156.55   208.55   239.51   266.36
326.03   301.58   299.80   350.87   326.36   271.29   290.33
316.71   333.64   359.05   153.74   114.87   100.43    50.14 <--- Station masses
```

```
8.69   7.75   6.71   6.00   6.40   7.09   7.14
6.55   6.04   6.16   6.05   5.74   5.99   6.21
6.24   5.91   5.46   5.45   4.63   6.96   6.99   <--- Station KGs
0.00   0.00   0.00   0.00   0.00   0.00   0.00
0.00   0.00   0.00   0.00   0.00   0.00   0.00
0.00   0.00   0.00   0.00   0.00   0.00   0.00   <--- Station roll gyradii
20.133       11.270       0.000       2.864       1.653   Bow overhang
17.935        8.840       0.000       1.121       0.647   Stern overhang
1 20.0 0.01              <----- Seakeeping position data
Bridge  SLAMWEDGE  MII              <----- Seakeeping position label and flags
3.0  0.0  13.0  12.14                <----- Seakeeping position coordinates
38.7  0.510                          <----- Wedge slamming parameters
0.25  0.17  60.0                     <----- MII tipping coefficients and time
1                                    <----- Number of bilge keel pairs
6  15                                <----- First and last stations spanned by bilge keel
 6.0  6.5  5.053  2.770  0.80        <----- Bilge keel data
 6.5  7.5  5.491  2.320  0.80
 7.5  8.5  5.750  2.000  0.80
 8.5  9.5  5.930  1.820  0.80
 9.5 10.5  6.054  1.725  0.80
10.5 11.5  6.104  1.700  0.80
11.5 12.5  6.029  1.705  0.80
12.5 13.5  5.870  1.735  0.80
13.5 14.5  5.541  1.850  0.80
14.5 15.0  5.167  2.190  0.80
15.7  1.8  7.5                       <----- Skeg
19.3 0.0 3.7 5.3 4.8 2.11 0.0 0      <----- Rudder data
0.0 0.0 0.0 0.0 0.0 0.0 0.0          <----- Rudder roll gains
0.0 0.0 0.0                          <----- Rudder yaw gains
4                                    <----- Number of stationary foil pairs
16.40  3.9  2.7  1.4   0.7  0.7  0.0  -105.5  1.0  <----- Shaft bracket data
16.40  1.8  2.5  1.4   0.7  0.7  0.0   -48.0  1.0
18.25  4.3  3.9  3.25  1.0  1.0  0.0  -104.5  1.0
18.25  0.6  3.4  3.4   1.0  1.0  0.0   -51.0  1.0
NOSTAB                               <----- Fin or tank stabilization
```

A.3 Sample Uni-Directional Point Spectrum

0.050	0.000
0.100	0.000
0.150	0.000
0.200	0.000
0.250	0.000
0.300	0.000
0.350	0.000
0.400	0.025
0.450	0.241
0.500	0.729
0.550	1.216
0.600	1.471
0.650	1.489
0.700	1.360
0.750	1.171
0.800	0.976
0.850	0.798
0.900	0.647
0.950	0.523
1.000	0.423
1.050	0.343
1.100	0.280
1.150	0.229
1.200	0.188
1.250	0.156
1.300	0.129
1.350	0.108
1.400	0.091
1.450	0.077
1.500	0.065
1.550	0.056
1.600	0.048
1.650	0.041
1.700	0.035
1.750	0.031
1.800	0.027
1.850	0.023
1.900	0.020
1.950	0.018
2.000	0.016

A.4 Input Format for Hindcast Directional Spectrum

When a hindcast directional spectrum is selected by the user (SPECTRUM = ODGPHINDCAST in Record (g)), spectral data are read from a formatted file specified in Record (h7). The contents of the file are as follows:

Record 1 - Labels for File Descriptors
Format (A89)

LABELS	Character*89	Labels for values on following line.

Record 2 - File Descriptors
Format (I2, I2, 1X, I2, I2, 1X, I6, 1X, F8.3, F8.2, 2X, F6.2, 2X, F6.2, 2X, F6.3, 4F8.2)

IYR	Integer	Last two digits of year.
IMON	Integer	Month.
IDAY	Integer	Day of month.
IHR	Integer	Hour (GMT).
IGRP	Integer	Grid point number.
LAT	Real	Latitude (degrees).
LONG	Real	Longitude (degrees).
WSPD	Real	Wind speed (m/s).
WDIR	Real	Wind direction (degrees) from which wind is approaching.
USHEAR	Real	Wind shear velocity (m/s).
HS	Real	Significant wave height (m).
TS	Real	Significant wave period (m).
VMD	Real	Mean direction (to) of energy propagation (degrees).
TP	Real	Peak wave period (s).

Record 3 - Blank

Record 4 - Wave Frequencies
Format (A9, 3X, 15F8.5)

LABEL	Character*9	Line label "FREQUENCY".
FREQ(15)	Real	Array of circular frequencies for energy components (Hz).

Record 5 - Direction Label

Format (A9)

LABEL	Character*9	Line label "DIRECTION".

Remaining Records - Directional Spectral Energies (Maximum 24 Records)

Format (F7.1, 4X, 15F8.5)

DIR	Real	Compass direction (to) for energy components on line (degrees).
E(15)	Real	Total energy for given direction and frequency (m^2).

Note: Each spectral energy record covers a directional range of 15 degrees; however, no records are given for directions with very low energies.

A.5 Sample Input Hindcast Directional Spectrum

YM DH	GP	LAT	LONG	M/SEC	FROM	U*	HSIG	TSIG	VMD	TPEAK
8403.1100.	1106.	46.250	-48.75	22.37	228.03	1.068	7.63	10.09	42.16	13.05

FREQUENCY	0.04047	0.04440	0.05000	0.05556	0.06111	0.06670	0.07222	0.08056	0.09167	0.10278	0.11667	0.13333	0.15833	0.20833	0.30833
DIRECTION															
7.5	0.00000	0.00001	0.00003	0.00008	0.00031	0.00158	0.00811	0.05596	0.05837	0.04476	0.04073	0.02203	0.01928	0.01060	0.00629
22.5	0.00001	0.00006	0.00023	0.00089	0.00466	0.02797	0.05777	0.11450	0.07939	0.04986	0.04366	0.02221	0.01972	0.01195	0.00766
37.5	0.00002	0.00025	0.00120	0.00856	0.04990	0.09320	0.09619	0.15493	0.09624	0.05620	0.04526	0.02335	0.02095	0.01334	0.00854
52.5	0.00016	0.00142	0.00888	0.05356	0.10226	0.11426	0.11143	0.17233	0.10130	0.05803	0.04656	0.02396	0.02159	0.01394	0.00870
67.5	0.00041	0.00221	0.00810	0.03030	0.05973	0.06665	0.07662	0.14635	0.09045	0.05231	0.04349	0.02267	0.02050	0.01332	0.00809
82.5	0.00029	0.00091	0.00190	0.00574	0.01212	0.01479	0.02060	0.07937	0.05429	0.03432	0.03395	0.01663	0.01774	0.01168	0.00688
97.5	0.00006	0.00016	0.00034	0.00076	0.00185	0.00119	0.00148	0.01006	0.00648	0.00404	0.00788	0.00565	0.00882	0.00911	0.00540
112.5	0.00001	0.00003	0.00002	0.00002	0.00002	0.00003	0.00006	0.00039	0.00035	0.00035	0.00078	0.00063	0.00208	0.00451	0.00403
127.5	0.00000	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000	0.00001	0.00001	0.00002	0.00003	0.00004	0.00017	0.00037	0.00315
247.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00002	0.00014	0.00011	0.00001	0.00000	0.00000	0.00000
262.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00002	0.00027	0.00149	0.00108	0.00015	0.00000	0.00000	0.00000
277.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00006	0.00133	0.00439	0.00258	0.00048	0.00002	0.00000	0.00000
292.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00011	0.00117	0.00518	0.00430	0.00102	0.00008	0.00000	0.00000
307.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00013	0.00121	0.00649	0.00820	0.00292	0.00075	0.00001	0.00000
322.5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00002	0.00017	0.00192	0.01268	0.02098	0.01694	0.01644	0.00831	0.00299
337.5	0.00000	0.00000	0.00000	0.00000	0.00001	0.00002	0.00005	0.00052	0.00626	0.01868	0.02533	0.01903	0.01764	0.00848	0.00360
352.5	0.00000	0.00000	0.00001	0.00001	0.00004	0.00014	0.00067	0.01539	0.03537	0.03097	0.03378	0.02158	0.01889	0.00958	0.00481

A.6 Input Format for User Input Directional Spectrum

When a user input directional spectrum is selected (SPECTRUM = INPUTDIR in Record (g)), spectral data is read from a formatted file specified in Record (h8). The contents of the file are as follows:

Record 1 - Spectrum Title
SPDIRTITLE (Columns 1-80)

SPDIRTITLE Alphanumeric title (maximum of 80 characters) which is written on output.

Record 2 - System of Units
SPDIRSYS (1 character string)

SPDIRSYS System of units for significant wave height and spectral density. The two possible inputs are:

BRITISH British units.

METRIC Metric units.

The units of wave height (ft or m) and spectral density (ft^2/(rad/s)/deg or m^2/(rad/s)/deg) may be chosen independently of the variable INSYS specified in Record (b) of the main input file.

Record 3 - Spectrum Parameters
NFREQSPDIR, HSSPDIR, TPSPDIR (1 integer, 2 reals)

NFREQSPDIR Number of frequencies for spectral density input (maximum 30).

HSSPDIR Significant wave height (ft or m).

TPSPDIR Characteristic wave period (ft or m).

Record 4 - Spectrum Frequencies
FREQSPDIR(I) (NFREQSPDIR reals)

FREQSPDIR(I) Frequencies for spectral energy densities (rad/s).

Records 4-39 - Sea Direction and Spectral Energy Densities
DIRSPDIR(IDIR), (DENSPDIR(IDIR, J), J = 1, NFREQSPDIR) (36 records, 1+NFREQSPDIR reals/record)

DIRSPDIR(IDIR) Sea direction (from) for spectral energy densities (degrees).

DENSPDIR(IDIR, J) Spectral energy densities (m^2/(rad/s)/deg or ft^2/(rad/s)/deg).

Note: Sea directions DIRSPDIR must begin at 0 degrees and increase in 10 degree increments to a maximum of 350 degrees. The program will terminate if this convention is not followed.

B SHIPMO7 Output

B.1 Post-Processor Output

Frequency responses and RMS motions may be stored on disk for post-processing by specifying OUTPPR = OUTPPR in Record (b). Data will then be written into a sequential, unformatted binary file specified in Record (b1).

Contents of the post-processing file are given below. Variables with parenthesis beside them are arrays.

Header with Ship and Wave Characteristics

The SHIPMO7 post-processing file begins with ten records giving the ship dimensions and the wave characteristics. The header also gives array dimensions, which must agree with the array dimensions for the program reading the post-processing file.

Record 1 - Source Program Name

PROGRAM	Char*20	Character string "SHIPMO7.0" identifying program name.

Record 2 - Parameters for Array Sizes

NWVFREQMAX	Integer	Maximum number of wave frequencies (40).
NENFREQMAX	Integer	Maximum number of encounter frequencies (40).
NSTLOADMAX	Integer	Maximum number stations for loads (21).
NPOSMAX	Integer	Maximum number of seakeeping positions (10).

Record 3 - Title and Control Variables

TITLE(10)	Char*10	Alphanumeric title with time and date appended.
OUTSYS	Char*20	Output units (BRITISH or METRIC).
WATERTYPE	Char*20	Water type (SALT or FRESH).
HYMETHOD	Char*20	Method for computing hydrodynamic coefficients (BOUND-2D or CONFORMAL).
SPECTRUM	Char*20	Spectrum type (REGULAR, QUADRATIC, BRETSCHNEIDER, JONSWAP, OCHIHUBBLE, INPUTUNI, TENPARAMETER, ODGPHINDCAST, or INPUTDIR)

Record 4 - Ship Dimensions

SHIPLEN	Real	Ship length between perpendiculars (ft or m).
NST	Integer	Number of stations (typically 21).

DISP	Real	Ship displacement (tons or tonnes).
LCBFP	Real	Distance from forward perpendicular to LCB (ft or m).
DRAFTMID	Real	Draft at midships (ft or m).
TRIMST	Real	Trim by stern (ft or m).
KG	Real	Height of CG above baseline (ft or m).
TRIMST	Real	Trim by stern (ft or m).
BEAMMID	Real	Beam at midships (ft or m).

Record 5 - Physical Constants

WDENSITY	Real	Water density (slugs/ft^3 or kg/m^3).
GRAVITY	Real	Gravitational acceleration (ft/s^2 or m/s^2).

Record 6 - Stations for Sea Load Computations

NSTLOAD	Integer	Number of stations for sea load computations.
XSTLOAD(I)	Real	Array of dimension NSTLOAD with station numbers for sea loads.

Record 7 - Ship Speeds

NSPEED	Integer	Number of ship speeds.
SPDKNOT(I)	Real	Array of dimension NSPEED with ship speeds (knots).

Record 8 - Sea directions

NSEADIR	Integer	Number of ship speeds.
SEADIR(I)	Real	Array of dimension NSEADIR with sea directions.

Record 9 - Seaways

NSEAWAY	Integer	Number of seaways.
HSW(NSEAWAY)	Real	Array of significant wave heights (ft or m).
TSW(NSEAWAY)	Real	Array of characteristic wave periods (s).

Record 10 - Wave frequencies

NWVFREQ	Integer	Number of wave frequencies.
WVFREQMIN	Real	Minimum wave frequency (rad/s).
DWVFREQ	Real	Wave frequency increment (rad/s).

Ship Motions and Loads in Regular and Irregular Seas for each Ship Speed

The remaining sequence of records is repeated for each ship speed. For regular seas and irregular seas with a principal wave direction, the sea direction index J in the motion and load arrays corresponds to the sea direction relative to the ship forward speed (Figure 5). For irregular seas without a principal wave direction (SPECTRUM = TENPARAMETER, ODGPHINDCAST, or INPUTDIR), the direction index J corresponds to the ship compass heading (Figure 6) for the irregular responses only.

Record 11 - Complex Motions in Unit Amplitude Regular Waves for Seaway 1

CSURGEREG(I,J)	Complex	Complex surge amplitude (ft/ft or m/m).
CSWAYREG(I,J)	Complex	Complex sway amplitude (ft/ft or m/m).
CHEAVEREG(I,J)	Complex	Complex heave amplitude (ft/ft or m/m).
CROLLREG(I,J)	Complex	Complex roll amplitude (rad/ft or rad/m).
CPITCHREG(I,J)	Complex	Complex pitch amplitude (rad/ft or rad/m).
CYAWREG(I,J)	Complex	Complex yaw amplitude (rad/ft or rad/m).
CRUDREG(I,J)	Complex	Complex rudder amplitude (rad/ft or rad/m).
CSTABREG(I,J)	Complex	Complex fin or U-tube tank amplitude (rad/ft or rad/m).

Notes: The above arrays have dimensions (NWVFREQMAX, NSEADIRMAX).

Regular wave motions and loads are given only for the first seaway regardless of the number of seaways.

Record 12 - Complex Sea Loads in Unit Amplitude Regular Waves for Seaway 1

CHORSHRREG(I,J,K)	Complex	Complex horizontal shear amplitude (lb/ft or N /m).
CVERTSHRREG(I,J,K)	Complex	Complex vertical shear amplitude (lb/ft or N/m).
CTORSIONREG(I,J,K)	Complex	Complex torsion amplitude (lb·ft/ft or N·m/m).
CVERTBNDREG(I,J,K)	Complex	Complex vertical bending moment amplitude (lb ·ft/ft or N·m/m).
CHORBNDREG(I,J,K)	Complex	Complex horizontal bending moment amplitude (lb·ft/ft or N·m/m).

Notes: This record is only written if the number of load stations NSTLOAD is 1 or greater.

The above arrays have dimensions (NWVFREQMAX, NSEADIRMAX, NSTLOADMAX).

Within the motions and loads written for each ship speed, the following sequence of RMS responses in irregular seas is repeated for each seaway if SPECTRUM is not equal to REGULAR.

Record 13 - RMS Motions at Ship Centre of Gravity

RMSSURGE(I)	Real	RMS surge (ft or m).
RMSSWAY(I)	Real	RMS sway (ft or m).
RMSHEAVE(I)	Real	RMS heave (ft or m).
RMSROLL(I)	Real	RMS roll (degrees).
RMSPITCH(I)	Real	RMS pitch (degrees).
RMSYAW(I)	Real	RMS yaw (degrees).
RMSRUD(I)	Real	RMS rudder deflection (degrees).
RMSSTAB(I)	Real	RMS stabilizer deflection (degrees).
RMSSURGEVEL(I)	Real	RMS surge velocity (ft/s or m/s).
RMSSWAYVEL(I)	Real	RMS sway velocity (ft/s or m/s).
RMSHEAVEVEL(I)	Real	RMS heave velocity (ft/s or m/s).
RMSROLLVEL(I)	Real	RMS roll velocity (deg/s).
RMSPITCHVEL(I)	Real	RMS pitch velocity (deg/s).
RMSYAWVEL(I)	Real	RMS yaw velocity (deg/s).
RMSRUDVEL(I)	Real	RMS rudder velocity (deg/s).
RMSSTABVEL(I)	Real	RMS stabilizer velocity (deg/s).
RMSSURGEACC(I)	Real	RMS surge acceleration (g).
RMSSWAYACC(I)	Real	RMS sway acceleration (g).
RMSHEAVEACC(I)	Real	RMS heave acceleration (g).
RMSROLLACC(I)	Real	RMS roll acceleration (deg/s^2).
RMSPITCHACC(I)	Real	RMS pitch acceleration (deg/s^2).
RMSYAWACC(I)	Real	RMS yaw acceleration (deg/s^2).
RMSRUDACC(I)	Real	RMS rudder acceleration (deg/s^2).
RMSSTABACC(I)	Real	RMS stabilizer acceleration (deg/s^2).

Note: The above arrays have dimension (NSEADIRMAX).

Record 14 - RMS Motions at Seakeeping Positions

RMSVERTDISP(I,J)	Real	RMS vertical displacement (ft or m).
RMSVERTVEL(I,J)	Real	RMS vertical velocity (ft/s or m/s).
RMSVERTACC(I,J)	Real	RMS vertical acceleration (g).
RMSRELDISP(I,J)	Real	RMS relative vertical displacement (ft or m).
RMSRELVEL(I,J)	Real	RMS relative vertical velocity (ft/s or m/s).
RMSLATDISP(I,J)	Real	RMS lateral displacement (ft or m).
RMSLATVEL(I,J)	Real	RMS lateral velocity (ft/s or m/s).
RMSLATACC(I,J)	Real	RMS lateral acceleration (g).
RMSLATFE(I,J)	Real	RMS lateral force estimator (g).
RMSGFEPORT(I,J)	Real	RMS force estimator function for tips or slides to port (g).
RMSGFEPORTVEL(I,J)	Real	RMS time derivative of port estimator (g/s).
RMSGFESTAR(I,J)	Real	RMS force estimator function for tips or slides to starboard (g).
RMSGFESTARVEL(I,J)	Real	RMS time derivative of starboard estimator (g/s).
RMSLONGDISP(I,J)	Real	RMS longitudinal displacement (ft or m).
RMSLONGVEL(I,J)	Real	RMS longitudinal velocity (ft/s or m/s).
RMSLONGACC(I,J)	Real	RMS longitudinal acceleration (g).
RMSLONGFE(I,J)	Real	RMS longitudinal force estimator (g).
RMSGFEFORE(I,J)	Real	RMS force estimator function for tips or slides forward (g).
RMSGFEFOREVEL(I,J)	Real	RMS time derivative of forward estimator (g/s).
RMSGFEAFT(I,J)	Real	RMS force estimator function for tips or slides aft (g).
RMSGFEAFTVEL(I,J)	Real	RMS time derivative of aft estimator (g/s).

Note: The above arrays have dimensions (NSEADIRMAX, NPOSMAX).

Record 15 - RMS Sea Loads

RMSHORSHR(I,J)	Real	RMS horizontal shear (lb or N).
RMSHORSHRVEL(I,J)	Real	RMS time derivative of horizontal shear (lb/s or N/s).
RMSVERTSHR(I,J)	Real	RMS vertical shear (lb or N).
RMSVERTSHRVEL(I,J)	Real	RMS time derivative of vertical shear (lb/s or N/s).
RMSTORSION(I,J)	Real	RMS torsion (lb·ft or N·m).
RMSTORSIONVEL(I,J)	Real	RMS time derivative of torsion (lb·ft/s or N·m /s).
RMSVERTBND(I,J)	Real	RMS vertical bending moment (lb·ft or N·m).
RMSVERTBNDVEL(I,J)	Real	RMS time derivative of vertical bending moment (lb·ft/s or N·m/s).
RMSHORBND(I,J)	Real	RMS horizontal bending moment (lb·ft or N·m).
RMSHORBNDVEL(I,J)	Real	RMS time derivative of horizontal bending moment (lb·ft/s or N·m/s).

Notes: This record is only written if the number of load station NSTLOAD is 1 or greater.

The above arrays have dimensions (NSEADIRMAX, NSTLOADMAX).

B.2 Output for Example Ship

```
Output from program SHIPMO7
Defence Research Establishment Atlantic
Program Version 7.0 - February 1997

SHIPMO Run Title:                                                        03-Feb-97 08:52:55
SHIPMO7 Example - CPF


***************  ECHO OF USER INPUT  ***************

Main Control Variables
Input system INSYS              : METRIC
Output system OUTSYS            : METRIC
Water type WATERTYPE            : SALT
Speed correction SPEEDCOR       : BOWSPEEDCOR
Swell correction SWELLCOR       : BOWSWELLCOR
RAO output OUTRAO               : MODAMP
Postprocessing output OUTPPR    : OUTPPR

Output postprocessing file : cpfexamp.ppr

Additional control variables
Load computation flag LOADFLAG : LOAD
Added resistance flag RAWFLAG  : RAW

Wave frequency parameters (rad/s)
Minimum WVFREQMIN :      0.200
Maximum WVFREQMAX :      2.000
Increment DWVFREQ :      0.100

Hydrodynamic coefficient control variables
Save to file parameter SAVEHY         : WRITEHY
Computation method HYMETHOD           : BOUND2D
End effect flag HYEND                 : LATLONG
Low frequency heave correction LOWHVCOR  : HVCOR

Hydrodynamic coefficients written to file : cpfexamp.hy


Encounter frequency parameters (rad/s)
Minimum ENFREQMIN :      0.200
Maximum ENFREQMAX :      6.000
Increment DENFREQ :      0.200
```

```
INPUT OPERATING CONDITIONS AND SPEEDS

Wave Spectrum
Type SPECTRUM : BRETSCHNEIDER
Sea direction parameters for spectrum with single dominant direction
Number of sea directions NSEADIR :  7
Spreading angle SPREADANG        :      0.00 degrees

Sea directions (degrees)
    0.0     30.0     60.0     90.0    120.0    150.0    180.0

Seaway Description
Number of seaways NSEAWAY :  1
Spectrum type : BRETSCHNEIDER
   HSW (m)        TSW (s)
     3.250          9.700

Number of ship speeds NSPEED :  1
Array of ship speeds (knots) SPDKNOT
  18.00
```

INPUT SHIP PARAMETERS

```
Ship length SHIPLEN               :  124.500 m
Center of gravity above keel KG  :    6.230 m
Pitch radius of gyration PITCHRG :   29.815 m

Metacentric height and roll radius
Metacentric height flag GMFLAG          : GMINPUT
Roll radius of gyration flag ROLLRGDEF : WETROLLRG
User input metacentric height GMUSER :    1.135 m
Wet radius of gyration WETROLLRG       :    5.200 m

Hull definition
Hull definition flag HULLDEF           : OFFSETS
Total number of ship stations NST      : 21
Number of stations with offsets NSTOFF : 21
Beam scale factor BEAMSF               :    0.0010
Draft scale factor DRAFTSF             :    0.0010

User has input hull offsets
Following values include keel ZAUSERBL (m)  before scaling by DRAFTSF
```

XST(I)	NOFFUSER(I)	ZAUSERBL(I,1)
0.000	12	4630.000
1.000	20	126.000
2.000	21	0.000
3.000	22	0.000
4.000	21	0.000
5.000	21	0.000
6.000	21	0.000
7.000	23	0.000
8.000	22	0.000
9.000	20	0.000
10.000	20	0.000
11.000	20	0.000
12.000	20	0.000
13.000	21	0.000
14.000	22	0.000
15.000	22	0.000
16.000	22	517.000
17.000	20	1880.000
18.000	20	2970.000
19.000	18	3670.000
20.000	14	4630.000

```
Input trim definition TRIMDEF    : DISP
Input displacement DISPUSER      :    4731.7998  tonne
Input FP to CG, LCGFPUSER        :   64.553 m
```

INPUT SEA LOADS PARAMETERS

Number of stations for load calculations : 1
Station numbers
10.000

Input mass distribution

Station	SECTTN tonne	SECTKG (m)	SECTRRG (m)
0	25.6900	8.690	0.000
1	79.0400	7.750	0.000
2	123.1800	6.710	0.000
3	156.5500	6.000	0.000
4	208.5500	6.400	0.000
5	239.5100	7.090	0.000
6	266.3600	7.140	0.000
7	326.0300	6.550	0.000
8	301.5800	6.040	0.000
9	299.8000	6.160	0.000
10	350.8700	6.050	0.000
11	326.3600	5.740	0.000
12	271.2900	5.990	0.000
13	290.3300	6.210	0.000
14	316.7100	6.240	0.000
15	333.6400	5.910	0.000
16	359.0500	5.460	0.000
17	153.7400	5.450	0.000
18	114.8700	4.630	0.000
19	100.4300	6.960	0.000
20	50.1400	6.990	0.000

Bow overhang mass distribution

Mass BOWTN	:	20.1330 tonne
Vertical CG location BOWKG	:	11.2700 m
Roll radius of gyration BOWRRG	:	0.0000 m
Hor distance of CG from FP BOWCGFP (must be positive)	:	2.8640 m
Pitch radius of gyration BOWPRG	:	1.6530 m

Stern overhang mass distribution

Mass STERNTN	:	17.9350 tonne
Vertical CG location STERNKG	:	8.8400 m
Roll radius of gyration STERNRRG	:	0.0000 m
Hor distance of CG from AP STERNCGAP (must be positive)	:	1.1210 m
Pitch radius of gyration STERNPRG	:	0.6470 m

INPUT SEAKEEPING POSITIONS

```
Number of positions NPOS                :    1
Time for slams SLAMHOUR                 :   20.000 hours
Slam exceedence probability SLAMEX      :  0.01000

Position number                         :  1
Position label POSLABEL                 : BRIDGE
Relative motion flag RELMOCALC          : SLAMWEDGE
MII calculation flag MIIFLAG            : MII
Station number XSTPOS                   :    3.000
Lateral offset YPOS                     :    0.000 m
Height above baseline ZPOSBL            :   13.000 m
Deck height above baseline DECKHBL      :   12.140 m
Slamming calculations based on wedge
Deadrise angle DEADR                    :   38.700 degrees
Pressure height limit SLHEIGHT          :    0.510 m
Input for Motion-induced Interruptions (MIIs)
Lateral tip coefficient TCLAT           :  0.2500
Longitudinal tip coefficient TCLONG     :  0.1700
Time of operation TIMEOP                :  60.000 s
INPUT BILGE KEEL DATA

Number of bilge keel pairs NBKPAIR :  1

Data for bilge keel pair        :  1
First station spanned IFIRSTBK  :  6
Last station spanned ILASTBK    : 15
```

Station	XSTBKFOR	XSTBKAFT	YBK (m)	ZBKBL (m)	BBK (m)
6	6.000	6.500	5.053	2.770	0.800
7	6.500	7.500	5.491	2.320	0.800
8	7.500	8.500	5.750	2.000	0.800
9	8.500	9.500	5.930	1.820	0.800
10	9.500	10.500	6.054	1.725	0.800
11	10.500	11.500	6.104	1.700	0.800
12	11.500	12.500	6.029	1.705	0.800
13	12.500	13.500	5.870	1.735	0.800
14	13.500	14.500	5.541	1.850	0.800
15	14.500	15.000	5.167	2.190	0.800

INPUT SKEG DATA

```
Station of aftmost point XSTAFTSKEG :    15.700
Breadth BSKEG                       :     1.800 m
Length ELSKEG                       :     7.500 m
```

INPUT RUDDER DATA

Station number XSTRUD	:	19.300
Lateral offset YRTRUD	:	0.000 m
Height relative to baseline ZRTRUDBL	:	3.700 m
Span SPANRUD	:	5.300 m
Root chord RCRUD	:	4.800 m
Tip chord TCRUD	:	2.110 m
Lift curve slope CLAORUD	:	0.000 /radian
Rudder in slipstream flag ISLIPRUD	:	0

Rudder roll gains

Roll acceleration gain RAGNRUD	:	0.0000 sec**2
Roll velocity gain RVGNRUD	:	0.0000 sec
Roll gain RGNRUD	:	0.0000
System natural frequency FREQRUD	:	0.0000 rad/s
System damping ratio DAMPRUD	:	0.0000
Low frequency cut-off FREQLRUD	:	0.0000 rad/s
High frequency cut-off FREQHRUD	:	0.0000 rad/s

Rudder yaw gains

Yaw acceleration gain YAGNRUD	:	0.0000 sec**2
Yaw velocity gain YVGNRUD	:	0.0000 sec
Yaw gain YGNRUD	:	0.0000

INPUT STATIONARY FOIL DATA

Number of stationary foil pairs NFOILPAIR : 4

Dimensions for stationary foils

XSTFOIL	YRTFOIL	ZRTFOILBL	SPANFOIL	RCFOIL	TCFOIL	CLAOFOIL	DIFOIL
	(m)	(m)	(m)	(m)	(m)	(/rad)	(degrees)
16.400	3.900	2.700	1.400	0.700	0.700	0.000	-105.500
16.400	1.800	2.500	1.400	0.700	0.700	0.000	-48.000
18.250	4.300	3.900	3.250	1.000	1.000	0.000	-104.500
18.250	0.600	3.400	3.400	1.000	1.000	0.000	-51.000

INPUT FIN OR TANK STABILIZATION DATA

Type of stabilization FINTANKSTAB : NOSTAB

*************** DEFAULT PARAMETERS BASED ON USER INPUT ***************

All sectional radii of gyration to be determined by ship radius of gyration

Default parameters for rudder
Lift curve slope (/rad) CLAORUD : 3.1762

Default parameters for stationary foil 1
Lift curve slope (/rad) CLAOFOIL(I) : 3.6064

Default parameters for stationary foil 2
Lift curve slope (/rad) CLAOFOIL(I) : 3.6064

Default parameters for stationary foil 3
Lift curve slope (/rad) CLAOFOIL(I) : 4.2738

Default parameters for stationary foil 4
Lift curve slope (/rad) CLAOFOIL(I) : 4.3265

*************** TRIMMED COORDINATES FOR APPENDAGES ***************

All X values given relative to ship CG

Bilge keel pair 1
Z given relative to waterline and to baseline
Y,Z coordinates given for root of bilge keel and for nearest point on hull

		Bilge keel			Hull			
Station	X (m)	Y (m)	Z wrt BL (m)	Z wrt WL (m)	Y (m)	Z wrt BL (m)	Z wrt WL (m)	Separation (m)
6	27.203	5.053	2.770	-2.282	5.049	2.773	-2.279	0.006
7	20.978	5.491	2.320	-2.725	5.461	2.344	-2.702	0.042
8	14.753	5.750	2.000	-3.038	5.752	1.998	-3.040	0.002
9	8.528	5.930	1.820	-3.212	5.927	1.824	-3.208	0.004
10	2.303	6.054	1.725	-3.300	6.057	1.722	-3.303	0.004
11	-3.922	6.104	1.700	-3.318	6.100	1.704	-3.314	0.006
12	-10.147	6.029	1.705	-3.307	6.031	1.703	-3.309	0.003
13	-16.372	5.870	1.735	-3.270	5.866	1.741	-3.264	0.006
14	-22.597	5.541	1.850	-3.148	5.535	1.860	-3.138	0.008
15	-28.822	5.167	2.190	-2.801	5.156	2.206	-2.785	0.016

Skeg
X value of skeg centroid : -30.679 m

Rudder root
X : -55.589 m
Y offset : 0.000 m
Z relative to CG : -2.470 m

Static foil root coordinates

Foil	X (m)	Y (m)	Z (m) (relative to CG)
1	-37.537	3.900	-3.489
2	-37.537	1.800	-3.689
3	-49.053	4.300	-2.277
4	-49.053	0.600	-2.777

```
***************  OFFSETS FOR TRIMMED SHIP  ***************

Vertical offsets given relative to baseline elevation at midships
X coordinates given relative to LCG
  Number of stations : 21
  Units              : m
  Draft at midships  :      5.025 m
  LCG from FP        :     64.553 m

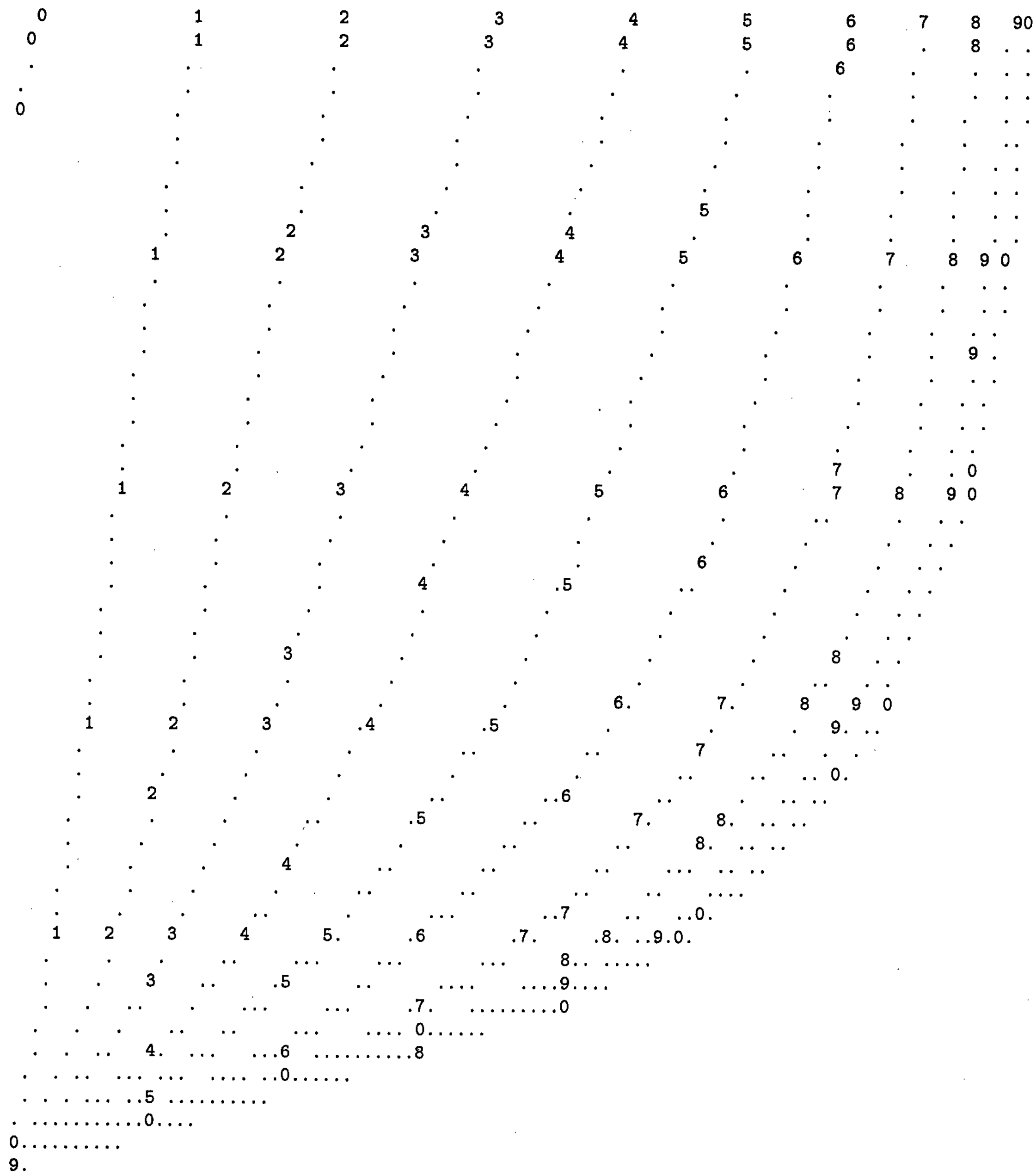
Station  0     X =   64.553
YA     :     0.000   0.110   0.129
ZA     :     4.563   4.933   5.025
Station  1     X =   58.328
YA     :     0.000   0.290   0.515   0.735   0.974   1.000   1.255   1.283
ZA     :     0.065   0.939   1.939   2.939   3.939   4.039   4.939   5.025
Station  2     X =   52.103
YA     :     0.000   0.721   1.000   1.166   1.552   1.930   2.000   2.334   2.369
ZA     :    -0.054   0.946   1.554   1.946   2.946   3.946   4.125   4.946   5.025
Station  3     X =   45.878
YA     :     0.000   1.000   1.160   1.837   2.000   2.390   2.913   3.000   3.426   3.463
ZA     :    -0.047   0.753   0.953   1.953   2.233   2.953   3.953   4.121   4.953   5.025
Station  4     X =   39.653
YA     :     0.000   1.000   1.665   2.000   2.588   3.000   3.306   3.916   4.000   4.446
             4.478
ZA     :    -0.040   0.433   0.960   1.284   1.960   2.511   2.960   3.960   4.110   4.960
             5.025
Station  5     X =   33.428
YA     :     0.000   1.000   2.000   2.268   3.000   3.470   4.000   4.273   4.869   5.000
             5.330   5.354
ZA     :    -0.034   0.269   0.794   0.966   1.521   1.966   2.588   2.966   3.966   4.228
             4.966   5.025
Station  6     X =   27.203
YA     :     0.000   1.000   2.000   2.971   3.000   4.000   4.373   5.000   5.204   5.702
             6.000   6.057   6.073
ZA     :    -0.027   0.161   0.507   0.973   0.989   1.652   1.973   2.674   2.973   3.973
             4.797   4.973   5.025
Station  7     X =   20.978
YA     :     0.000   1.000   2.000   3.000   3.713   4.000   4.573   5.000   5.190   5.979
             6.000   6.360   6.622   6.633
ZA     :    -0.020   0.130   0.344   0.660   0.980   1.122   1.480   1.810   1.980   2.980
             3.020   3.980   4.980   5.025
Station  8     X =   14.753
YA     :     0.000   1.000   2.000   3.000   4.000   4.340   5.000   5.165   5.754   6.000
             6.493   6.812   7.000   7.020   7.027
ZA     :    -0.013   0.137   0.325   0.514   0.831   0.987   1.372   1.487   1.987   2.248
             2.987   3.987   4.885   4.987   5.025
Station  9     X =    8.528
YA     :     0.000   1.000   2.000   3.000   4.000   4.724   5.000   6.000   6.122   6.814
             7.000   7.104   7.267   7.272
ZA     :    -0.007   0.143   0.331   0.518   0.725   0.993   1.133   1.871   1.993   2.993
             3.531   3.993   4.993   5.025
Station 10     X =    2.303
YA     :     0.000   1.000   2.000   3.000   4.000   4.895   5.000   6.000   6.348   6.989
             7.000   7.258   7.398   7.401
ZA     :     0.000   0.150   0.338   0.525   0.715   1.000   1.046   1.668   2.000   3.000
             3.027   4.000   5.000   5.025
```

*************** OFFSETS FOR TRIMMED SHIP ***************

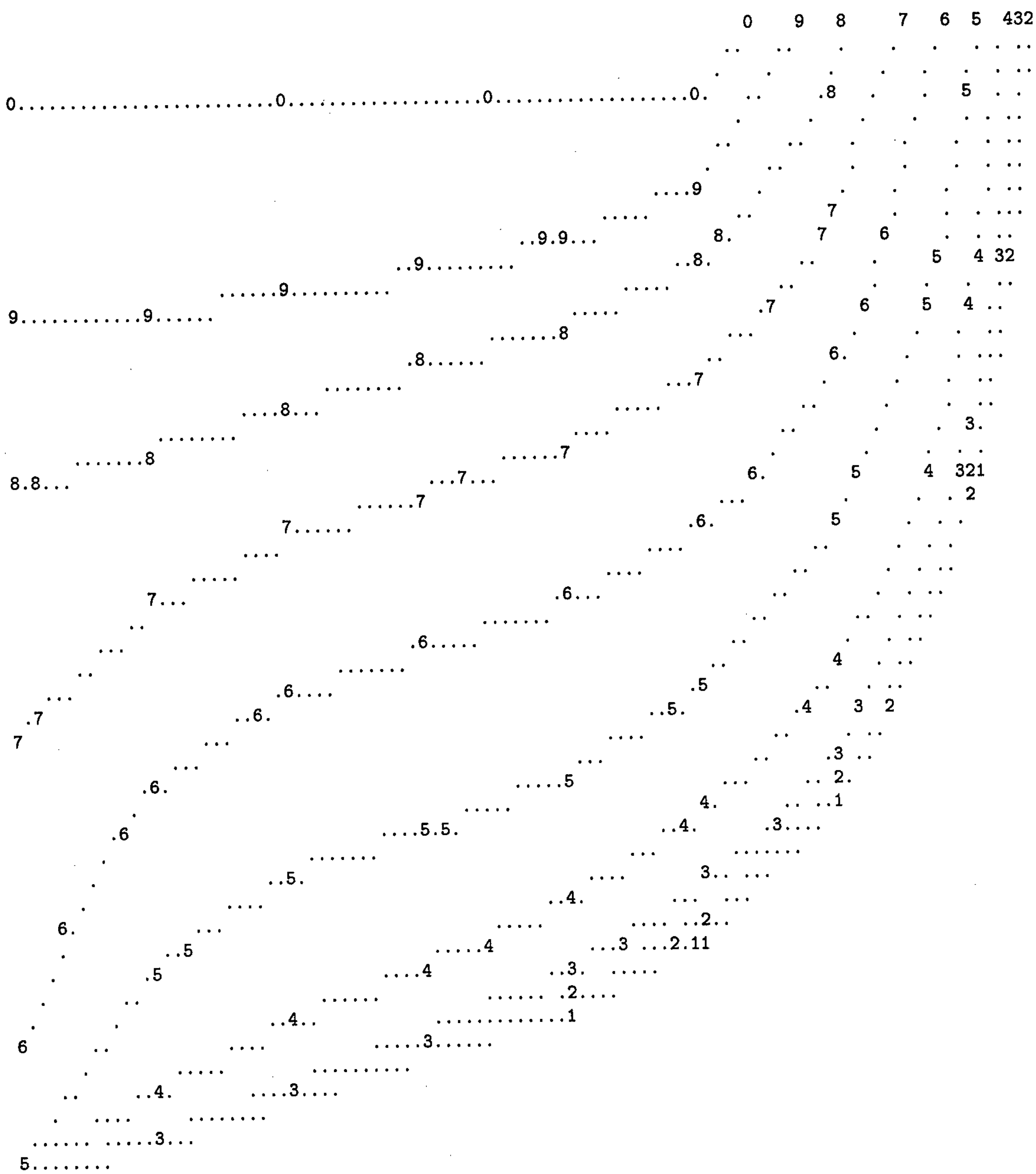
Vertical offsets given relative to baseline elevation at midships
X coordinates given relative to LCG
  Number of stations : 21
  Units   : m
  Draft at midships :   5.025 m
  LCG from FP   :   64.553 m

Station 11	X =	-3.922								
YA :	0.000	1.000	2.000	3.000	4.000	4.940	5.000	6.000	6.416	7.000
	7.043	7.312	7.446	7.448						
ZA :	0.007	0.157	0.345	0.532	0.720	1.007	1.032	1.618	2.007	2.906
	3.007	4.007	5.007	5.025						
Station 12	X =	-10.147								
YA :	0.000	1.000	2.000	3.000	4.000	4.824	5.000	6.000	6.348	7.000
	7.006	7.300	7.446	7.447						
ZA :	0.013	0.163	0.351	0.538	0.746	1.013	1.087	1.687	2.013	3.000
	3.013	4.013	5.013	5.025						
Station 13	X =	-16.372								
YA :	0.000	1.000	2.000	3.000	4.000	4.433	5.000	5.527	6.000	6.181
	6.895	7.000	7.225	7.390	7.391					
ZA :	0.020	0.170	0.378	0.609	0.879	1.020	1.245	1.520	1.856	2.020
	3.020	3.265	4.020	5.020	5.025					
Station 14	X =	-22.597								
YA :	0.000	1.000	2.000	3.000	3.437	4.000	4.896	5.000	5.777	6.000
	6.673	6.988	7.000	7.060	7.260					
ZA :	0.027	0.372	0.674	0.922	1.027	1.182	1.527	1.576	2.027	2.203
	3.027	3.777	3.816	4.027	5.025					
Station 15	X =	-28.822								
YA :	0.000	1.000	1.183	2.000	3.000	3.085	4.000	4.787	5.000	6.000
	6.183	6.668	6.780	7.000	7.061					
ZA :	0.034	0.931	1.034	1.315	1.517	1.534	1.754	2.034	2.132	2.827
	3.034	3.784	4.034	4.741	5.025					
Station 16	X =	-35.047								
YA :	0.000	0.341	0.759	1.000	1.716	2.000	3.000	4.000	5.000	5.376
	6.000	6.216	6.385	6.804						
ZA :	0.557	1.040	1.540	1.722	2.040	2.115	2.300	2.505	2.843	3.040
	3.534	3.790	4.040	5.025						
Station 17	X =	-41.272								
YA :	0.000	0.178	1.000	2.000	3.000	3.293	4.000	5.000	5.568	5.892
	6.000	6.499								
ZA :	1.927	2.047	2.500	2.797	2.991	3.047	3.199	3.508	3.797	4.047
	4.156	5.025								
Station 18	X =	-47.497								
YA :	0.000	0.148	1.000	2.000	3.000	4.000	5.000	5.131	6.000	6.107
ZA :	3.024	3.054	3.207	3.372	3.542	3.729	3.999	4.054	4.731	5.025
Station 19	X =	-53.722								
YA :	0.000	1.000	2.000	3.000	3.871	4.000	5.000	5.767		
ZA :	3.731	3.800	3.872	3.955	4.061	4.081	4.347	5.025		
Station 20	X =	-59.947								
YA :	0.000	2.000	3.500	5.000	5.384					
ZA :	4.697	4.697	4.697	4.697	5.025					

BODY PLAN FOR TRIMMED SHIP, STATIONS 0 TO 10



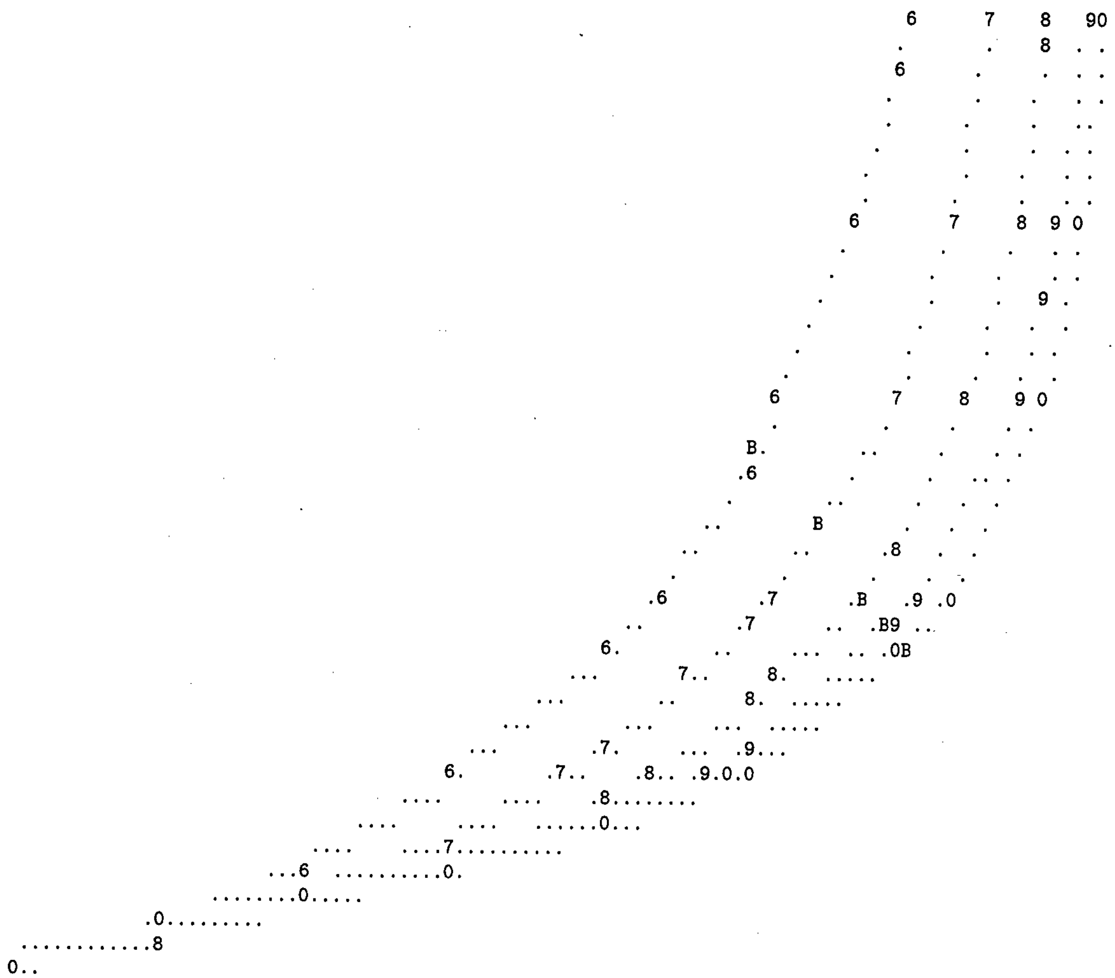
BODY PLAN FOR TRIMMED SHIP, STATIONS 11 TO 20



APPENDAGES AND ASSOCIATED STATIONS FOR TRIMMED SHIP, STATIONS 0 TO 10

Legend (in order of precedence for plotting)

B	Bilge keel root
S	Stablizing fin
F	Static foil
R	Rudder
K	Aft portion of skeg
0-9	Last digit of station for offset point
.	Interpolated offset point



APPENDAGES AND ASSOCIATED STATIONS FOR TRIMMED SHIP, STATIONS 11 TO 20

```
   Legend (in order of precedence for plotting)
   B          Bilge keel root
   S          Stablizing fin
   F          Static foil
   R          Rudder
   K          Aft portion of skeg
   0-9        Last digit of station for offset point
   .          Interpolated offset point

                                                                              9    8         6  5  432
                                                                             ..    .        .   . . ..
                                                                           ..     8        .   5  . ..
                                                                         ..     ..        .    . . ..
                                                                       ..    ...         .    .  . ..
                                                                   ..9.    ..            .   .   . ..
                                                            .......      ..             .    .  .  ..
                                                  ....9.9...          .8.              6    5   4 ..
                               ..........9.......           F   .....8                .    .   .  32
  R    ........9...........9..                            .F....                     6     5   4 ...
  R....                                           ........8. F                       ..     .   .  ..
  R                                  ....8.....          F                        6      .    . ...
  R       FF               .8........                    F                      ..     ..   . .  ..
  R         F   ...........                              F                   ...      .     .  3..
  R    ......F.8                                         F                 ..       .     .  . .
  R.8..       FF                                        F               ..6         5      4  321
  R             F                                       F           .6..          5.     .. ...1
  R              FF                                    FF       .....           ..      .  . ..
  R                F                                   FF  .....             ...      ..  .  ..
  R                 FF    FF                      ...FF.6.                 ..        . ..  .
  R                   F     FF           .6.......   FF                 ...        ..  .  .
  R                    F      F.........            F F               .B          4  .  .
  R                     FF..6..FF                   FF            5..5         4.. 3. 2.
  R                  ..... F      F                F F       .....          ...    . ..1
  R              ....      FF      FF              FF   5....           ...B   B.3...
  R            .6            F      F           .F.F...              ...    .. .BB
  R         6.                F       FF..5.5.... FF              .4.4    .3.....
  R        ..                  .FF......         F F          ....      .......
  R       .              ...5.   F              F      .....      .3......
  R     ..          .....        FF             F.....4      ..... 2...
  R   6          ..5.                F      ....4F.        ..3. ..2.11
  R   .        .5                  ..FF..4.     F   ...3.........
  R..        ..            4......          ..........2...
  R        ..          .....          ...3..........
  R      ..       ......       ..........2
  R    ..    ...4.     ......3....
  R .. ..... ..3.......
  R...........
  R
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  R
```

```
*************** GENERAL HULL PARAMETERS AND HYDROSTATIC CALCULATIONS  ***************

Hull defined by sectional offsets, displacement, and LCG

Hull dimensions in trimmed condition
 Ship length              :       124.500 m
 Displacement             :     4731.8013 tonne
 LCB (and LCG) from FP    :        64.553 m
 Draft at midships        :         5.025 m
 Trim by stern            :        -0.135 m  (positive for baseline lower at stern than at bow)
 KG                       :         6.230 m  (height of CG above baseline)
 Draft at CG              :         5.023 m
 Height of CG above water :         1.207 m

Following definitions used for sectional dimensions:
Beam     - Width at waterline
Draft    - Depth below waterline of keel (y=0)
Breadth - Maximum width of section  (can be greater than beam)
Area coefficient = Area/(Beam*Draft)

Ship coefficients based on midships section
  Beam                              :    14.803 m
  Draft (depth of baseline)         :     5.025 m
  Block coefficient Cb              :     0.498
  Prismatic coefficient Cp          :     0.621
  Vertical prismatic coefficient Cvp :     0.636

Wetted hull area including ends   :     1985.337 m **2

Metacentric height GM for roll motion calculations based on user input
  User input GM  :     1.135 m  (can include free surface effects)
  Hydrostatic GM :     1.372 m  (no free surface effects)

Heave, roll, and pitch properties
  Heave natural frequency        :     1.220 rad/s
  Heave natural period           :     5.150 seconds
  Roll radius of gyration (dry)  :     4.506 m
  Dry roll gyradius/Ship beam    :     0.304
  Wet roll radius of gyration    :     5.200 m
  Roll natural frequency         :     0.642 rad/s
  Roll natural period            :     9.793 seconds
  Pitch radius of gyration (dry) :    29.815 m
  Pitch gyradius/Ship length     :     0.239
  Pitch natural frequency        :     1.286 rad/s
  Pitch natural period           :     4.887 seconds
```

SECTIONAL PROPERTIES

X coordinates given relative to ship CG

Station	X (m)	Beam (m)	Draft (m)	Breadth (m)	Area Co.
0	64.553	0.258	0.462	0.258	0.553
1	58.328	2.567	4.960	2.567	0.509
2	52.103	4.737	5.079	4.737	0.562
3	45.878	6.925	5.072	6.925	0.590
4	39.653	8.955	5.065	8.955	0.625
5	33.428	10.707	5.059	10.707	0.671
6	27.203	12.146	5.052	12.146	0.719
7	20.978	13.265	5.045	13.265	0.760
8	14.753	14.054	5.038	14.054	0.785
9	8.528	14.544	5.032	14.544	0.797
10	2.303	14.803	5.025	14.803	0.803
11	-3.922	14.896	5.018	14.896	0.804
12	-10.147	14.895	5.012	14.895	0.799
13	-16.372	14.781	5.005	14.781	0.784
14	-22.597	14.519	4.998	14.519	0.737
15	-28.822	14.122	4.991	14.122	0.638
16	-35.047	13.609	4.468	13.609	0.569
17	-41.272	12.999	3.098	12.999	0.616
18	-47.497	12.213	2.001	12.213	0.700
19	-53.722	11.533	1.294	11.533	0.780
20	-59.947	10.769	0.328	10.769	0.964

SECTIONAL MASS DISTRIBUTION FOR LOAD CALCULATIONS

Sectional roll radii of gyration given relative to ship center of gravity

Station	Mass (tonne)	Center of gravity above BL (m)	Center of gravity above CG (m)	Roll radius of gyration (m)
Bow overhang	20.13300	11.270	4.967	5.125
0.00	25.69000	8.690	2.390	3.076
1.00	79.04000	7.750	1.457	2.809
2.00	123.18000	6.710	0.424	3.027
3.00	156.55000	6.000	-0.280	3.391
4.00	208.55000	6.400	0.127	3.902
5.00	239.50999	7.090	0.824	4.260
6.00	266.35999	7.140	0.881	4.495
7.00	326.03000	6.550	0.297	4.886
8.00	301.57999	6.040	-0.206	4.695
9.00	299.79999	6.160	-0.079	4.677
10.00	350.87000	6.050	-0.182	5.062
11.00	326.35999	5.740	-0.486	4.903
12.00	271.29001	5.990	-0.229	4.454
13.00	290.32999	6.210	-0.002	4.602
14.00	316.70999	6.240	0.034	4.806
15.00	333.64001	5.910	-0.289	4.942
16.00	359.04999	5.460	-0.732	5.170
17.00	153.74001	5.450	-0.735	3.429
18.00	114.87000	4.630	-1.549	3.283
19.00	100.43000	6.960	0.788	2.819
20.00	50.14000	6.990	0.825	2.828
Stern overhang	17.93500	8.840	2.676	3.285

Comparison of input inertial parameters with values computed from load mass distribution

		Input	Mass distribution
Roll gyradius	:	4.506 m	4.506 m
Pitch gyradius	:	29.815 m	29.815 m
Displacement	:	4731.80127 tonne	4731.78809 tonne
LCGFP	:	64.553 m	64.553 m
KG	:	6.230 m	6.230 m

*************** POSITIONS FOR SEAKEEPING CALCULATIONS ***************

Number of seakeeping positions : 1

X is given relative to ship CG
Vertical dimensions are given relative to following :
  BL - baseline
  CG - center of gravity
  WL - waterline
Waterline refers to static waterline (no forward speed effects)

Label	Station	X	Y	Z wrt BL	Z wrt CG	Z wrt WL	Draft	Deck wrt BL	Freeboard
		(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
BRIDGE	3.000	45.878	0.000	13.000	6.720	7.928	5.072	12.140	7.068

SLAMMING CALCULATION PARAMETERS

Time period SLAMHOUR : 20.000 hours
Extreme probability SLAMEX : 0.010000

Slam pressure at keel related to form factor by:
    Pressure = SLFORM x 1/2 x Water density x (Relative velocity)**2

SLWIDTH is effective width for slam pressure Sectional slam force given by:
    Force/per unit length = SLWIDTH x Pressure

Label	Station	Input	Form factor	Effective width (m)
BRIDGE	3.000	Wedge	3.725	0.637

MOTION INDUCED INTERRUPTION (MII) PARAMETERS

Label	Station	Tipping Coefficients Longitudinal	Tipping Coefficients Lateral	Time of Operation (seconds)
BRIDGE	3.000	0.170	0.250	60.000

SPECTRAL ENERGIES FOR SEAWAYS

```
Spectrum type  : Bretschneider
Minimum frequency   :     0.200 rad/s
Maximum frequency   :     2.000 rad/s
Frequency increment :     0.100 rad/s


Wave energies for seaway number  1
Input significant wave height :     3.250 m
Hs from wave spectral energy  :     3.230 m
Characteristic wave period    :     9.700 s
NATO sea state number         :  5
Unidirectional wave spectral energies S(w)*dw in m **2
  0.00000  0.00000  0.00105  0.05498  0.13679  0.13827  0.10363  0.07037  0.04663  0.03105
  0.02100  0.01449  0.01020  0.00733  0.00536  0.00399  0.00301  0.00231  0.00179
```

DYNAMIC WATERLINE AND SWELL COEFFICIENT DUE TO SHIP FORWARD SPEED

```
Ship speed     :   18.000 knots
Froude number  :    0.265
```

Station	XA (rel CG) (m)	Steady wave (m)	Swell coefficient
0	64.553	0.232	1.081
1	58.328	0.993	1.241
2	52.103	0.645	1.139
3	45.878	0.171	1.009
4	39.653	-0.160	0.877
5	33.428	-0.367	0.796
6	27.203	-0.465	0.805
7	20.978	-0.490	0.885
8	14.753	-0.462	0.997
9	8.528	-0.329	1.063
10	2.303	-0.173	1.071
11	-3.922	-0.049	1.032
12	-10.147	-0.068	1.003
13	-16.372	-0.159	0.958
14	-22.597	-0.315	0.976
15	-28.822	-0.410	1.005
16	-35.047	-0.300	0.996
17	-41.272	-0.063	0.982
18	-47.497	0.099	0.980
19	-53.722	0.085	1.003
20	-59.947	0.000	1.000

SHIP MOTIONS AT CG IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 0.0 degrees (180 degrees for head seas)

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Some wave frequencies have encounter frequencies below lower limit for accurate motion computations.
RAOs obtained by interpolation from other wave frequencies.
Lower limit on encounter frequency : 0.140 rad/s, 0.500*SQRT(G/L)
Wave frequencies (rad/s) with revised RAOs
0.900
1.000
1.100

Surge, sway, and heave nondimensionalized by wave amplitude A
Roll, pitch, and yaw nondimensionalized by wave slope KA

Wave	Surge		Sway		Heave		Roll		Pitch		Yaw		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	1.456	-82	0.000	0	0.988	0	0.000	0	0.993	91	0.000	0	0.162	12.373
0.300	1.829	-84	0.000	0	0.945	0	0.000	0	0.959	92	0.000	0	0.215	5.499
0.400	2.279	-85	0.000	0	0.843	0	0.000	0	0.878	95	0.000	0	0.249	3.093
0.500	2.760	-85	0.000	0	0.664	0	0.000	0	0.735	100	0.000	0	0.264	1.980
0.600	3.139	-85	0.000	0	0.416	-1	0.000	0	0.535	105	0.000	0	0.260	1.375
0.700	3.155	-83	0.000	0	0.157	-10	0.000	0	0.315	109	0.000	0	0.237	1.010
0.800	2.344	-77	0.000	0	0.051	-140	0.000	0	0.132	115	0.000	0	0.195	0.773
0.900	1.818	-78	0.000	0	0.030	-136	0.000	0	0.102	114	0.000	0	0.135	0.611
1.000	1.294	-80	0.000	0	0.009	-115	0.000	0	0.072	112	0.000	0	0.055	0.495
1.100	0.773	-85	0.000	0	0.014	15	0.000	0	0.042	106	0.000	0	0.043	0.409
1.200	0.281	-108	0.000	0	0.035	27	0.000	0	0.014	77	0.000	0	0.161	0.344
1.300	0.179	115	0.000	0	0.039	-127	0.000	0	0.021	-102	0.000	0	0.297	0.293
1.400	0.134	105	0.000	0	0.039	-43	0.000	0	0.035	-16	0.000	0	0.452	0.253
1.500	0.041	-119	0.000	0	0.037	28	0.000	0	0.030	79	0.000	0	0.626	0.220
1.600	0.026	-88	0.000	0	0.022	138	0.000	0	0.025	175	0.000	0	0.819	0.193
1.700	0.017	65	0.000	0	0.005	123	0.000	0	0.024	-84	0.000	0	1.031	0.171
1.800	0.006	-103	0.000	0	0.044	123	0.000	0	0.023	17	0.000	0	1.262	0.153
1.900	0.004	-20	0.000	0	0.045	164	0.000	0	0.016	116	0.000	0	1.511	0.137
2.000	0.007	68	0.000	0	0.047	-127	0.000	0	0.008	-142	0.000	0	1.780	0.124

ADDED RESISTANCE IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 0.0 degrees (180 degrees for head seas)

Added resistance in waves non-dimensionalized by RHO*G*B*B/(L*A*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave Frequency	Added Resistance	Wavelength/ Ship length
0.200	0.000	12.373
0.300	0.002	5.499
0.400	0.057	3.093
0.500	0.359	1.980
0.600	0.987	1.375
0.700	1.184	1.010
0.800	0.567	0.773
0.900	-0.396	0.611
1.000	-0.506	0.495
1.100	0.349	0.409
1.200	0.048	0.344
1.300	0.651	0.293
1.400	1.287	0.253
1.500	1.081	0.220
1.600	1.486	0.193
1.700	1.026	0.171
1.800	1.266	0.153
1.900	0.698	0.137
2.000	-0.099	0.124

ROLL DAMPING COEFFICIENTS

Ship heading : 0.0 degrees (180 degrees for head seas)
Ship speed : 18.0 knots
Froude number : 0.265

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Damping coefficients non-dimensionaled by 2*C44HULL/ROLLNF
(roll damping given as fraction of criteral damping
Roll added mass given as fraction of dry roll inertia
Roll natural frequency : 0.642 rad/s
Roll stiffness : 0.5267E+08 N-m
Roll inertia (dry) : 0.9608E+08 N-m**2

Damping components from the following :
Total - All roll damping components
Wave - Wave radiation damping
Lift - Lift forces on skeg, static foils, stabilizing fins, rudders, and bilge keels
Eddy - Eddy-making forces on hull, including skeg
Skin - Skin friction force on hull
Visc BK - Viscous forces on bilge keel
Visc Foils - Viscous forces on static foils, stabilizing fins, and rudders

Wave	Enc	Roll			Damping Components					Added
Freq	Freq	Amp	Total	Wave	Lift	Eddy	Skin	Visc BK	Visc Foils	Mass
0.200	0.162	0.000	0.101	0.014	0.088	0.000	0.000	0.000	0.000	0.309
0.300	0.215	0.000	0.102	0.014	0.087	0.000	0.000	0.000	0.000	0.310
0.400	0.249	0.000	0.102	0.014	0.087	0.000	0.000	0.000	0.000	0.311
0.500	0.264	0.000	0.102	0.014	0.087	0.000	0.000	0.000	0.000	0.312
0.600	0.260	0.000	0.102	0.014	0.087	0.000	0.000	0.000	0.000	0.312
0.700	0.237	0.000	0.102	0.014	0.087	0.000	0.000	0.000	0.000	0.311
0.800	0.195	0.000	0.101	0.014	0.087	0.000	0.000	0.000	0.000	0.309
0.900	0.135	0.000	0.101	0.014	0.088	0.000	0.000	0.000	0.000	0.309
1.000	0.055	0.000	0.101	0.014	0.088	0.000	0.000	0.000	0.000	0.309
1.100	0.043	0.000	0.101	0.014	0.088	0.000	0.000	0.000	0.000	0.309
1.200	0.161	0.000	0.101	0.014	0.088	0.000	0.000	0.000	0.000	0.309
1.300	0.297	0.000	0.102	0.015	0.087	0.000	0.000	0.000	0.000	0.313
1.400	0.452	0.000	0.104	0.017	0.087	0.000	0.000	0.000	0.000	0.321
1.500	0.626	0.000	0.111	0.024	0.086	0.000	0.000	0.000	0.000	0.329
1.600	0.819	0.000	0.127	0.041	0.086	0.000	0.000	0.000	0.000	0.327
1.700	1.031	0.000	0.150	0.065	0.085	0.000	0.000	0.000	0.000	0.302
1.800	1.262	0.000	0.164	0.081	0.083	0.000	0.000	0.000	0.000	0.264
1.900	1.511	0.000	0.162	0.080	0.082	0.000	0.000	0.000	0.000	0.235
2.000	1.780	0.000	0.152	0.071	0.081	0.000	0.000	0.000	0.000	0.221

SHIP LOADS IN REGULAR WAVES

Ship heading : 0.0 degrees (180 degrees for head seas)
Ship speed : 18.0 knots
Froude number : 0.265

Station : 10.000

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Horizontal and vertical shear non-dimensionalized by (0.001 RHO*G*B*L*A)

Torsion, vertical, and horizontal moments non-dimensionalized by (0.001 RHO*G*B*L*L*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave	Hor Shear		Vert Shear		Torsion Mom		Vert Moment		Hor Moment		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.000	0	0.185	-12	0.000	0	0.201	-178	0.000	0	0.162	12.373
0.300	0.000	0	1.160	-3	0.000	0	1.353	-178	0.000	0	0.215	5.499
0.400	0.000	0	3.447	18	0.000	0	4.455	-171	0.000	0	0.249	3.093
0.500	0.000	0	7.880	45	0.000	0	10.020	-165	0.000	0	0.264	1.980
0.600	0.000	0	16.840	68	0.000	0	16.863	-162	0.000	0	0.260	1.375
0.700	0.000	0	30.522	77	0.000	0	21.645	-163	0.000	0	0.237	1.010
0.800	0.000	0	46.504	68	0.000	0	21.942	-174	0.000	0	0.195	0.773
0.900	0.000	0	32.100	67	0.000	0	15.782	-175	0.000	0	0.135	0.611
1.000	0.000	0	17.726	64	0.000	0	9.637	-178	0.000	0	0.055	0.495
1.100	0.000	0	3.748	39	0.000	0	3.582	171	0.000	0	0.043	0.409
1.200	0.000	0	11.398	-99	0.000	0	2.993	31	0.000	0	0.161	0.344
1.300	0.000	0	45.409	165	0.000	0	7.491	-91	0.000	0	0.297	0.293
1.400	0.000	0	86.608	-178	0.000	0	9.723	-4	0.000	0	0.452	0.253
1.500	0.000	0	41.072	-158	0.000	0	7.318	110	0.000	0	0.626	0.220
1.600	0.000	0	27.740	132	0.000	0	8.993	-142	0.000	0	0.819	0.193
1.700	0.000	0	44.252	162	0.000	0	7.350	-37	0.000	0	1.031	0.171
1.800	0.000	0	18.801	-133	0.000	0	5.306	87	0.000	0	1.262	0.153
1.900	0.000	0	18.674	122	0.000	0	5.590	-133	0.000	0	1.511	0.137
2.000	0.000	0	32.302	-164	0.000	0	6.826	17	0.000	0	1.780	0.124

SHIP MOTIONS AT CG IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 30.0 degrees (180 degrees for head seas)

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Some wave frequencies have encounter frequencies below lower limit for accurate motion computations.
RAOs obtained by interpolation from other wave frequencies.
Lower limit on encounter frequency : 0.140 rad/s, 0.500*SQRT(G/L)
Wave frequencies (rad/s) with revised RAOs
1.100
1.200
1.300

Surge, sway, and heave nondimensionalized by wave amplitude A
Roll, pitch, and yaw nondimensionalized by wave slope KA

Wave	Surge		Sway		Heave		Roll		Pitch		Yaw		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	1.188	-82	0.570	97	0.990	0	0.723	68	0.862	90	0.588	-10	0.167	12.373
0.300	1.440	-84	0.604	100	0.956	0	0.800	71	0.837	92	0.649	-8	0.226	5.499
0.400	1.729	-85	0.600	106	0.873	0	0.839	73	0.779	95	0.722	-5	0.269	3.093
0.500	2.023	-86	0.526	117	0.727	0	0.890	74	0.676	100	0.796	-2	0.295	1.980
0.600	2.245	-86	0.390	146	0.513	0	0.924	74	0.525	106	0.842	2	0.305	1.375
0.700	2.259	-85	0.436	-148	0.263	-3	0.893	74	0.341	114	0.827	8	0.299	1.010
0.800	1.877	-83	0.863	-106	0.059	-42	0.739	76	0.162	122	0.712	19	0.276	0.773
0.900	0.915	-70	1.335	-77	0.090	-147	0.447	85	0.039	140	0.496	43	0.237	0.611
1.000	1.028	68	1.559	-27	0.099	-159	0.104	135	0.033	-100	0.328	110	0.182	0.495
1.100	0.840	73	1.255	-37	0.078	-160	0.090	124	0.024	-103	0.247	104	0.110	0.409
1.200	0.662	81	1.009	-52	0.056	-162	0.080	111	0.015	-110	0.171	93	0.022	0.344
1.300	0.505	94	0.873	-74	0.035	-166	0.074	95	0.007	-133	0.110	67	0.083	0.293
1.400	0.395	116	0.896	-99	0.014	179	0.076	78	0.006	137	0.099	19	0.204	0.253
1.500	0.239	105	0.134	-54	0.044	-24	0.059	87	0.025	-10	0.026	120	0.341	0.220
1.600	0.049	-130	0.099	21	0.047	30	0.111	165	0.029	78	0.015	140	0.495	0.193
1.700	0.051	-96	0.005	143	0.031	129	0.083	160	0.024	166	0.007	-35	0.665	0.171
1.800	0.019	56	0.023	-153	0.019	-161	0.054	-126	0.021	-98	0.001	-89	0.851	0.153
1.900	0.004	63	0.006	25	0.009	-115	0.016	15	0.019	2	0.003	103	1.054	0.137
2.000	0.009	-89	0.011	-34	0.041	163	0.007	53	0.016	94	0.002	-52	1.273	0.124

ADDED RESISTANCE IN REGULAR WAVES

```
   Ship speed     :      18.0 knots
   Froude number  :     0.265
   Ship heading   :      30.0 degrees (180 degrees for head seas)
```

Added resistance in waves non-dimensionalized by RHO*G*B*B/(L*A*A)

```
where      RHO = Water density
            G  = gravitational acceleration
            B  = ship beam
            L  = ship length
            A  = wave amplitude
```

Wave Frequency	Added Resistance	Wavelength/ Ship length
0.200	0.002	12.373
0.300	0.010	5.499
0.400	0.075	3.093
0.500	0.394	1.980
0.600	1.270	1.375
0.700	2.333	1.010
0.800	2.151	0.773
0.900	0.867	0.611
1.000	0.291	0.495
1.100	-0.394	0.409
1.200	-0.330	0.344
1.300	0.305	0.293
1.400	0.217	0.253
1.500	1.054	0.220
1.600	1.139	0.193
1.700	1.341	0.171
1.800	0.962	0.153
1.900	1.424	0.137
2.000	0.901	0.124

ROLL DAMPING COEFFICIENTS

```
   Ship heading  :      30.0 degrees (180 degrees for head seas)
   Ship speed    :      18.0 knots
   Froude number :     0.265

Viscous roll damping based on irregular seaway
   Spectrum                 :        Bretschneider
   Sea state                :  5
   Significant wave height :      3.250 m
   Characteristic period   :      9.700 seconds

Damping coefficients non-dimensionaled by 2*C44HULL/ROLLNF
(roll damping given as fraction of criteral damping
Roll added mass given as fraction of dry roll inertia
  Roll natural frequency :        0.642 rad/s
  Roll stiffness          :  0.5267E+08 N-m
  Roll inertia (dry)      :  0.9608E+08 N-m**2

Damping components from the following :
  Total       - All roll damping components
  Wave        - Wave radiation damping
  Lift        - Lift forces on skeg, static foils, stabilizing fins, rudders, and bilge keels
  Eddy        - Eddy-making forces on hull, including skeg
  Skin        - Skin friction force on hull
  Visc BK     - Viscous forces on bilge keel
  Visc Foils - Viscous forces on static foils, stabilizing fins, and rudders
```

Wave	Enc	Roll	Damping Components							Added
Freq	Freq	Amp	Total	Wave	Lift	Eddy	Skin	Visc BK	Visc Foils	Mass
0.200	0.167	2.067	0.131	0.014	0.088	0.000	0.000	0.030	0.000	0.309
0.300	0.226	2.067	0.136	0.014	0.087	0.000	0.000	0.034	0.000	0.310
0.400	0.269	2.067	0.138	0.014	0.087	0.000	0.000	0.036	0.000	0.312
0.500	0.295	2.067	0.140	0.015	0.087	0.000	0.000	0.038	0.000	0.313
0.600	0.305	2.067	0.141	0.015	0.087	0.000	0.000	0.038	0.000	0.314
0.700	0.299	2.067	0.140	0.015	0.087	0.000	0.000	0.038	0.000	0.313
0.800	0.276	2.067	0.139	0.015	0.087	0.000	0.000	0.037	0.000	0.312
0.900	0.237	2.067	0.136	0.014	0.087	0.000	0.000	0.034	0.000	0.311
1.000	0.182	2.067	0.132	0.014	0.088	0.000	0.000	0.031	0.000	0.309
1.100	0.110	2.067	0.129	0.014	0.088	0.000	0.000	0.027	0.000	0.309
1.200	0.022	2.067	0.129	0.014	0.088	0.000	0.000	0.027	0.000	0.309
1.300	0.083	2.067	0.129	0.014	0.088	0.000	0.000	0.027	0.000	0.309
1.400	0.204	2.067	0.134	0.014	0.087	0.000	0.000	0.032	0.000	0.309
1.500	0.341	2.067	0.143	0.015	0.087	0.000	0.000	0.040	0.000	0.315
1.600	0.495	2.067	0.153	0.019	0.087	0.000	0.000	0.047	0.000	0.323
1.700	0.665	2.067	0.168	0.028	0.086	0.000	0.000	0.053	0.000	0.329
1.800	0.851	2.067	0.190	0.045	0.085	0.000	0.001	0.059	0.000	0.324
1.900	1.054	2.067	0.217	0.067	0.084	0.000	0.001	0.064	0.000	0.298
2.000	1.273	2.067	0.235	0.081	0.083	0.000	0.001	0.070	0.000	0.262

SHIP LOADS IN REGULAR WAVES

Ship heading : 30.0 degrees (180 degrees for head seas)
Ship speed : 18.0 knots
Froude number : 0.265

Station : 10.000

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Horizontal and vertical shear non-dimensionalized by (0.001 RHO*G*B*L*A)

Torsion, vertical, and horizontal moments non-dimensionalized by (0.001 RHO*G*B*L*L*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave	Hor Shear		Vert Shear		Torsion Mom		Vert Moment		Hor Moment		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.486	176	0.122	-16	0.022	-63	0.118	-177	0.144	-133	0.167	12.373
0.300	1.191	178	0.873	-7	0.035	-89	0.960	-178	0.384	-140	0.226	5.499
0.400	2.141	-177	2.450	14	0.090	-88	3.332	-168	0.860	-142	0.269	3.093
0.500	3.129	-166	5.261	47	0.190	-91	7.904	-160	1.740	-142	0.295	1.980
0.600	3.968	-141	11.832	79	0.342	-96	14.289	-153	3.161	-139	0.305	1.375
0.700	6.014	-98	24.298	100	0.513	-102	20.125	-148	4.992	-134	0.299	1.010
0.800	12.182	-64	38.654	110	0.615	-109	21.547	-146	6.576	-126	0.276	0.773
0.900	21.974	-44	43.879	106	0.537	-118	16.756	-153	6.830	-115	0.237	0.611
1.000	31.034	-25	43.124	82	0.248	-140	9.376	-168	5.102	-92	0.182	0.495
1.100	25.786	-27	28.803	84	0.212	-134	7.398	-168	4.092	-97	0.110	0.409
1.200	20.584	-30	14.533	88	0.179	-126	5.421	-167	3.138	-106	0.022	0.344
1.300	15.470	-35	2.117	169	0.151	-114	3.448	-165	2.312	-121	0.083	0.293
1.400	10.577	-45	14.471	-109	0.131	-99	1.491	-157	1.799	-148	0.204	0.253
1.500	14.411	-34	86.952	-173	0.164	-123	8.574	-8	1.500	-118	0.341	0.220
1.600	10.926	-30	63.556	-157	0.277	-11	7.480	103	0.964	-26	0.495	0.193
1.700	3.505	12	32.395	150	0.463	-28	9.919	-153	0.643	-17	0.665	0.171
1.800	5.658	17	56.617	152	0.245	41	8.578	-64	0.832	-155	0.851	0.153
1.900	5.338	-5	34.498	-169	0.139	155	6.362	47	0.692	74	1.054	0.137
2.000	8.375	35	10.227	115	0.329	-81	5.909	180	1.402	-55	1.273	0.124

SHIP MOTIONS AT CG IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 60.0 degrees (180 degrees for head seas)

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Some wave frequencies have encounter frequencies below lower limit for accurate motion computations.
RAOs obtained by interpolation from other wave frequencies.
Lower limit on encounter frequency : 0.140 rad/s, 0.500*SQRT(G/L)
Wave frequencies (rad/s) with revised RAOs
2.000

Surge, sway, and heave nondimensionalized by wave amplitude A
Roll, pitch, and yaw nondimensionalized by wave slope KA

Wave	Surge		Sway		Heave		Roll		Pitch		Yaw		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.588	-83	0.927	93	0.996	0	1.118	76	0.501	90	0.513	-8	0.181	12.373
0.300	0.653	-85	0.956	95	0.978	0	1.294	77	0.494	92	0.551	-7	0.257	5.499
0.400	0.720	-86	0.966	97	0.944	0	1.352	77	0.479	94	0.567	-8	0.324	3.093
0.500	0.786	-87	0.941	99	0.887	1	1.428	77	0.454	98	0.584	-8	0.382	1.980
0.600	0.840	-87	0.872	104	0.797	1	1.517	76	0.417	102	0.595	-7	0.430	1.375
0.700	0.867	-87	0.758	111	0.664	3	1.550	71	0.364	109	0.585	-7	0.468	1.010
0.800	0.851	-87	0.612	124	0.494	6	1.471	62	0.295	117	0.544	-8	0.498	0.773
0.900	0.773	-87	0.471	146	0.306	11	1.289	48	0.216	130	0.467	-8	0.517	0.611
1.000	0.622	-86	0.394	179	0.130	20	1.090	28	0.139	149	0.357	-7	0.528	0.495
1.100	0.403	-83	0.392	-148	0.016	118	0.946	8	0.076	-178	0.226	-5	0.528	0.409
1.200	0.153	-69	0.371	-124	0.066	-154	0.787	-7	0.046	-118	0.097	4	0.520	0.344
1.300	0.111	55	0.253	-96	0.067	-120	0.515	-16	0.043	-57	0.027	111	0.502	0.293
1.400	0.235	74	0.161	-14	0.059	-59	0.191	-35	0.039	-5	0.078	158	0.474	0.253
1.500	0.218	77	0.346	44	0.062	-4	0.126	-129	0.034	51	0.081	169	0.437	0.220
1.600	0.075	77	0.409	70	0.043	63	0.142	-143	0.029	110	0.037	-163	0.390	0.193
1.700	0.066	-125	0.204	145	0.044	155	0.031	-141	0.018	175	0.043	-35	0.335	0.171
1.800	0.120	151	0.720	-117	0.037	-138	0.072	64	0.009	-117	0.077	0	0.269	0.153
1.900	0.659	108	1.174	-69	0.013	-155	0.024	129	0.001	-70	0.056	64	0.194	0.137
2.000	0.659	108	1.174	-69	0.013	-155	0.024	129	0.001	-70	0.056	64	0.110	0.124

ADDED RESISTANCE IN REGULAR WAVES

```
   Ship speed     :     18.0 knots
   Froude number  :    0.265
   Ship heading   :     60.0 degrees (180 degrees for head seas)
```

Added resistance in waves non-dimensionalized by RHO*G*B*B/(L*A*A)

```
where      RHO = Water density
            G  = gravitational acceleration
            B  = ship beam
            L  = ship length
            A  = wave amplitude
```

Wave Frequency	Added Resistance	Wavelength/ Ship length
0.200	0.002	12.373
0.300	0.011	5.499
0.400	0.044	3.093
0.500	0.159	1.980
0.600	0.519	1.375
0.700	1.434	1.010
0.800	3.163	0.773
0.900	5.277	0.611
1.000	6.257	0.495
1.100	4.692	0.409
1.200	1.721	0.344
1.300	0.675	0.293
1.400	2.040	0.253
1.500	2.155	0.220
1.600	0.826	0.193
1.700	1.132	0.171
1.800	0.831	0.153
1.900	0.193	0.137
2.000	0.108	0.124

ROLL DAMPING COEFFICIENTS

```
   Ship heading  :      60.0 degrees (180 degrees for head seas)
   Ship speed    :      18.0 knots
   Froude number :     0.265

Viscous roll damping based on irregular seaway
   Spectrum               :      Bretschneider
   Sea state              :  5
   Significant wave height :     3.250 m
   Characteristic period  :      9.700 seconds

Damping coefficients non-dimensionaled by 2*C44HULL/ROLLNF
(roll damping given as fraction of criteral damping
Roll added mass given as fraction of dry roll inertia
  Roll natural frequency :       0.642 rad/s
  Roll stiffness         :  0.5267E+08 N-m
  Roll inertia (dry)     :  0.9608E+08 N-m**2

Damping components from the following :
  Total      - All roll damping components
  Wave       - Wave radiation damping
  Lift       - Lift forces on skeg, static foils, stabilizing fins, rudders, and bilge keels
  Eddy       - Eddy-making forces on hull, including skeg
  Skin       - Skin friction force on hull
  Visc BK    - Viscous forces on bilge keel
  Visc Foils - Viscous forces on static foils, stabilizing fins, and rudders
```

Wave	Enc	Roll	Damping Components							Added
Freq	Freq	Amp	Total	Wave	Lift	Eddy	Skin	Visc BK	Visc Foils	Mass
0.200	0.181	4.787	0.145	0.014	0.088	0.000	0.000	0.044	0.000	0.309
0.300	0.257	4.787	0.153	0.014	0.087	0.000	0.000	0.051	0.000	0.312
0.400	0.324	4.787	0.158	0.015	0.087	0.000	0.001	0.056	0.000	0.315
0.500	0.382	4.787	0.163	0.015	0.087	0.000	0.001	0.060	0.000	0.317
0.600	0.430	4.787	0.167	0.016	0.087	0.000	0.001	0.063	0.000	0.320
0.700	0.468	4.787	0.170	0.018	0.087	0.000	0.001	0.065	0.000	0.322
0.800	0.498	4.787	0.173	0.019	0.087	0.000	0.001	0.067	0.000	0.323
0.900	0.517	4.787	0.175	0.019	0.087	0.000	0.001	0.068	0.000	0.325
1.000	0.528	4.787	0.176	0.020	0.087	0.000	0.001	0.068	0.000	0.325
1.100	0.528	4.787	0.176	0.020	0.087	0.000	0.001	0.069	0.000	0.325
1.200	0.520	4.787	0.175	0.019	0.087	0.000	0.001	0.068	0.000	0.325
1.300	0.502	4.787	0.173	0.019	0.087	0.000	0.001	0.067	0.000	0.324
1.400	0.474	4.787	0.171	0.018	0.087	0.000	0.001	0.065	0.000	0.322
1.500	0.437	4.787	0.168	0.017	0.087	0.000	0.001	0.063	0.000	0.320
1.600	0.390	4.787	0.163	0.015	0.087	0.000	0.001	0.060	0.000	0.318
1.700	0.335	4.787	0.159	0.015	0.087	0.000	0.001	0.057	0.000	0.315
1.800	0.269	4.787	0.154	0.014	0.087	0.000	0.000	0.052	0.000	0.312
1.900	0.194	4.787	0.147	0.014	0.087	0.000	0.000	0.045	0.000	0.309
2.000	0.110	4.787	0.141	0.014	0.088	0.000	0.000	0.039	0.000	0.309

SHIP LOADS IN REGULAR WAVES

Ship heading : 60.0 degrees (180 degrees for head seas)
Ship speed : 18.0 knots
Froude number : 0.265

Station : 10.000

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Horizontal and vertical shear non-dimensionalized by (0.001 RHO*G*B*L*A)

Torsion, vertical, and horizontal moments non-dimensionalized by (0.001 RHO*G*B*L*L*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave	Hor Shear		Vert Shear		Torsion Mom		Vert Moment		Hor Moment		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.426	-179	0.015	-112	0.039	-61	0.047	-3	0.180	-121	0.181	12.373
0.300	1.062	-180	0.314	-26	0.054	-95	0.164	158	0.439	-129	0.257	5.499
0.400	1.893	178	0.646	-4	0.132	-94	0.890	-159	0.859	-134	0.324	3.093
0.500	2.808	177	0.858	58	0.277	-95	2.788	-145	1.560	-137	0.382	1.980
0.600	3.441	178	2.886	103	0.522	-98	6.177	-140	2.722	-138	0.430	1.375
0.700	3.131	-175	7.947	119	0.863	-104	11.046	-135	4.464	-138	0.468	1.010
0.800	1.486	-125	18.006	130	1.239	-113	17.146	-128	6.741	-136	0.498	0.773
0.900	5.530	-36	34.841	140	1.558	-125	23.498	-120	9.257	-134	0.517	0.611
1.000	14.887	-26	58.808	150	1.764	-140	28.462	-110	11.414	-131	0.528	0.495
1.100	27.013	-23	87.495	160	1.872	-156	30.189	-98	12.390	-127	0.528	0.409
1.200	38.526	-22	115.092	171	1.837	-171	27.528	-81	11.430	-121	0.520	0.344
1.300	44.612	-20	133.501	-177	1.483	176	20.920	-59	8.380	-112	0.502	0.293
1.400	41.220	-17	135.350	-164	0.818	154	12.267	-26	4.341	-86	0.474	0.253
1.500	27.905	-10	117.498	-152	0.517	84	4.338	45	2.776	-10	0.437	0.220
1.600	9.732	16	81.131	-149	0.622	46	7.278	167	3.398	38	0.390	0.193
1.700	9.879	142	43.462	-166	0.367	13	8.739	-143	2.264	80	0.335	0.171
1.800	16.057	170	31.984	-178	0.336	-64	5.994	-97	1.689	167	0.269	0.153
1.900	10.832	-170	12.951	-119	0.158	-90	0.546	-141	1.514	-129	0.194	0.137
2.000	10.832	-170	12.951	-119	0.158	-90	0.546	-141	1.514	-129	0.110	0.124

SHIP MOTIONS AT CG IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 90.0 degrees (180 degrees for head seas)

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Surge, sway, and heave nondimensionalized by wave amplitude A
Roll, pitch, and yaw nondimensionalized by wave slope KA

Wave	Surge		Sway		Heave		Roll		Pitch		Yaw		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.000	-164	0.974	89	1.000	0	1.227	90	0.002	102	0.085	98	0.200	12.373
0.300	0.000	-3	0.950	90	0.996	0	1.579	81	0.006	154	0.068	44	0.300	5.499
0.400	0.000	-1	0.924	91	1.002	0	1.833	72	0.002	111	0.043	-3	0.400	3.093
0.500	0.000	-1	0.913	93	1.011	0	2.253	54	0.006	71	0.050	-50	0.500	1.980
0.600	0.000	0	0.909	92	1.010	0	2.441	21	0.004	112	0.062	-109	0.600	1.375
0.700	0.000	0	0.857	90	1.025	-1	1.761	-13	0.005	100	0.050	-161	0.700	1.010
0.800	0.000	0	0.773	89	1.036	-1	1.061	-31	0.005	114	0.037	166	0.800	0.773
0.900	0.000	0	0.693	91	1.065	-3	0.668	-38	0.006	114	0.027	146	0.900	0.611
1.000	0.000	0	0.618	93	1.094	-6	0.450	-38	0.008	124	0.022	129	1.000	0.495
1.100	0.000	0	0.544	95	1.124	-13	0.318	-37	0.010	127	0.018	118	1.100	0.409
1.200	0.000	0	0.476	99	1.111	-22	0.236	-34	0.015	122	0.016	108	1.200	0.344
1.300	0.001	0	0.409	104	0.990	-35	0.178	-30	0.020	105	0.013	101	1.300	0.293
1.400	0.001	0	0.350	110	0.773	-47	0.138	-26	0.022	83	0.012	95	1.400	0.253
1.500	0.001	0	0.295	116	0.544	-52	0.107	-22	0.019	63	0.011	92	1.500	0.220
1.600	0.001	0	0.249	125	0.380	-51	0.084	-17	0.016	48	0.010	90	1.600	0.193
1.700	0.001	0	0.206	135	0.269	-45	0.066	-11	0.012	39	0.009	89	1.700	0.171
1.800	0.001	0	0.172	146	0.196	-37	0.052	-5	0.009	34	0.008	89	1.800	0.153
1.900	0.001	0	0.142	158	0.146	-27	0.040	1	0.006	35	0.007	90	1.900	0.137
2.000	0.001	0	0.118	172	0.109	-15	0.031	8	0.005	39	0.006	91	2.000	0.124

ADDED RESISTANCE IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 90.0 degrees (180 degrees for head seas)

Added resistance in waves non-dimensionalized by RHO*G*B*B/(L*A*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave Frequency	Added Resistance	Wavelength/ Ship length
0.200	-0.001	12.373
0.300	-0.003	5.499
0.400	0.011	3.093
0.500	0.065	1.980
0.600	0.188	1.375
0.700	0.172	1.010
0.800	1.469	0.773
0.900	1.649	0.611
1.000	1.830	0.495
1.100	2.010	0.409
1.200	2.191	0.344
1.300	2.371	0.293
1.400	2.552	0.253
1.500	2.732	0.220
1.600	2.913	0.193
1.700	3.093	0.171
1.800	3.274	0.153
1.900	3.454	0.137
2.000	3.635	0.124

ROLL DAMPING COEFFICIENTS

Ship heading : 90.0 degrees (180 degrees for head seas)
Ship speed : 18.0 knots
Froude number : 0.265

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Damping coefficients non-dimensionaled by 2*C44HULL/ROLLNF
(roll damping given as fraction of criteral damping
Roll added mass given as fraction of dry roll inertia
Roll natural frequency : 0.642 rad/s
Roll stiffness : 0.5267E+08 N-m
Roll inertia (dry) : 0.9608E+08 N-m**2

Damping components from the following :
Total - All roll damping components
Wave - Wave radiation damping
Lift - Lift forces on skeg, static foils, stabilizing fins, rudders, and bilge keels
Eddy - Eddy-making forces on hull, including skeg
Skin - Skin friction force on hull
Visc BK - Viscous forces on bilge keel
Visc Foils - Viscous forces on static foils, stabilizing fins, and rudders

Wave	Enc	Roll	Damping Components							Added
Freq	Freq	Amp	Total	Wave	Lift	Eddy	Skin	Visc BK	Visc Foils	Mass
0.200	0.200	4.044	0.144	0.014	0.087	0.000	0.000	0.042	0.000	0.309
0.300	0.300	4.044	0.153	0.015	0.087	0.000	0.000	0.050	0.000	0.314
0.400	0.400	4.044	0.160	0.015	0.087	0.000	0.000	0.057	0.000	0.318
0.500	0.500	4.044	0.169	0.019	0.087	0.000	0.001	0.062	0.000	0.324
0.600	0.600	4.044	0.177	0.022	0.086	0.000	0.001	0.067	0.000	0.329
0.700	0.700	4.044	0.189	0.031	0.086	0.000	0.001	0.072	0.000	0.329
0.800	0.800	4.044	0.202	0.039	0.086	0.000	0.001	0.076	0.000	0.329
0.900	0.900	4.044	0.217	0.051	0.085	0.000	0.001	0.080	0.000	0.318
1.000	1.000	4.044	0.232	0.063	0.085	0.000	0.001	0.084	0.000	0.308
1.100	1.100	4.044	0.244	0.071	0.084	0.000	0.001	0.087	0.000	0.290
1.200	1.200	4.044	0.255	0.080	0.084	0.000	0.001	0.090	0.000	0.273
1.300	1.300	4.044	0.259	0.081	0.083	0.001	0.001	0.093	0.000	0.258
1.400	1.400	4.044	0.264	0.083	0.083	0.001	0.001	0.096	0.001	0.244
1.500	1.500	4.044	0.264	0.080	0.082	0.001	0.001	0.099	0.001	0.236
1.600	1.600	4.044	0.263	0.078	0.082	0.001	0.001	0.102	0.001	0.228
1.700	1.700	4.044	0.262	0.074	0.081	0.001	0.001	0.104	0.001	0.224
1.800	1.800	4.044	0.261	0.070	0.081	0.001	0.001	0.107	0.001	0.220
1.900	1.900	4.044	0.259	0.066	0.080	0.001	0.001	0.110	0.001	0.219
2.000	2.000	4.044	0.257	0.063	0.080	0.001	0.001	0.112	0.001	0.218

SHIP LOADS IN REGULAR WAVES

Ship heading : 90.0 degrees (180 degrees for head seas)
Ship speed : 18.0 knots
Froude number : 0.265

Station : 10.000

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Horizontal and vertical shear non-dimensionalized by (0.001 RHO*G*B*L*A)

Torsion, vertical, and horizontal moments non-dimensionalized by (0.001 RHO*G*B*L*L*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave	Hor Shear		Vert Shear		Torsion Mom		Vert Moment		Hor Moment		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.149	-77	0.048	160	0.047	-58	0.127	0	0.154	-93	0.200	12.373
0.300	0.352	-106	0.047	-83	0.068	-109	0.297	31	0.349	-105	0.300	5.499
0.400	0.490	-134	0.193	146	0.193	-120	0.481	0	0.571	-117	0.400	3.093
0.500	0.732	-177	0.341	129	0.508	-140	0.645	0	0.744	-141	0.500	1.980
0.600	1.067	105	0.502	117	1.060	-174	0.930	0	0.584	158	0.600	1.375
0.700	1.289	31	0.806	100	1.359	150	1.079	0	0.694	40	0.700	1.010
0.800	1.560	-12	1.323	86	1.365	130	1.183	0	1.317	0	0.800	0.773
0.900	1.552	-37	2.176	72	1.347	120	1.039	4	1.915	-11	0.900	0.611
1.000	1.566	-52	3.527	60	1.346	116	0.681	23	2.613	-14	1.000	0.495
1.100	1.358	-60	5.510	46	1.342	114	0.920	102	3.278	-15	1.100	0.409
1.200	1.146	-67	8.122	33	1.340	115	2.554	117	4.096	-14	1.200	0.344
1.300	0.843	-65	10.586	17	1.321	116	4.747	106	4.730	-12	1.300	0.293
1.400	0.599	-60	12.366	5	1.303	120	6.408	94	5.384	-10	1.400	0.253
1.500	0.416	-51	13.238	-3	1.266	124	7.074	85	5.817	-6	1.500	0.220
1.600	0.320	-48	14.071	-6	1.233	129	7.207	82	6.148	-2	1.600	0.193
1.700	0.324	-85	14.636	-7	1.180	134	7.036	83	6.325	5	1.700	0.171
1.800	0.646	-113	15.032	-6	1.129	141	6.787	86	6.364	13	1.800	0.153
1.900	1.350	-122	14.996	-3	1.056	147	6.431	92	6.308	22	1.900	0.137
2.000	2.298	-123	14.690	2	0.980	155	5.984	100	6.156	33	2.000	0.124

SHIP MOTIONS AT CG IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 120.0 degrees (180 degrees for head seas)

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Surge, sway, and heave nondimensionalized by wave amplitude A
Roll, pitch, and yaw nondimensionalized by wave slope KA

Wave	Surge		Sway		Heave		Roll		Pitch		Yaw		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.403	96	0.762	87	1.000	0	1.266	95	0.499	-91	0.418	148	0.219	12.373
0.300	0.369	94	0.694	88	0.998	0	1.607	77	0.501	-93	0.278	156	0.343	5.499
0.400	0.336	93	0.647	91	1.002	0	2.294	45	0.507	-96	0.227	179	0.476	3.093
0.500	0.300	92	0.618	89	0.990	0	3.046	-18	0.508	-101	0.298	-174	0.618	1.980
0.600	0.262	92	0.488	86	0.978	0	1.921	-80	0.502	-107	0.245	171	0.770	1.375
0.700	0.220	91	0.366	88	0.972	-2	1.114	-111	0.483	-116	0.172	173	0.932	1.010
0.800	0.174	91	0.257	92	0.979	-9	0.704	-129	0.441	-130	0.123	-180	1.102	0.773
0.900	0.126	90	0.160	99	0.849	-31	0.442	-141	0.346	-153	0.087	-170	1.283	0.611
1.000	0.080	89	0.082	111	0.372	-58	0.250	-151	0.188	-179	0.057	-159	1.472	0.495
1.100	0.040	86	0.029	139	0.089	-18	0.109	-163	0.061	162	0.034	-144	1.672	0.409
1.200	0.012	72	0.013	-119	0.095	31	0.024	153	0.006	-161	0.017	-121	1.880	0.344
1.300	0.006	-52	0.021	-61	0.067	42	0.034	47	0.012	-60	0.008	-80	2.098	0.293
1.400	0.010	-71	0.020	-31	0.029	61	0.039	33	0.009	-53	0.005	-21	2.326	0.253
1.500	0.006	-73	0.014	2	0.010	124	0.024	29	0.004	-38	0.003	34	2.563	0.220
1.600	0.001	-74	0.008	48	0.008	-172	0.005	25	0.001	9	0.002	88	2.809	0.193
1.700	0.001	130	0.005	131	0.006	-118	0.006	-148	0.001	88	0.002	139	3.065	0.171
1.800	0.001	-146	0.005	-156	0.004	-73	0.006	-148	0.001	160	0.001	-166	3.331	0.153
1.900	0.002	-101	0.003	-119	0.001	-17	0.001	-129	0.000	-176	0.001	-71	3.606	0.137
2.000	0.001	-99	0.001	-25	0.001	87	0.002	29	0.000	133	0.001	-15	3.890	0.124

ADDED RESISTANCE IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 120.0 degrees (180 degrees for head seas)

Added resistance in waves non-dimensionalized by RHO*G*B*B/(L*A*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave Frequency	Added Resistance	Wavelength/ Ship length
0.200	-0.004	12.373
0.300	-0.008	5.499
0.400	0.043	3.093
0.500	0.312	1.980
0.600	0.394	1.375
0.700	1.339	1.010
0.800	4.449	0.773
0.900	8.994	0.611
1.000	7.209	0.495
1.100	2.463	0.409
1.200	2.550	0.344
1.300	2.732	0.293
1.400	2.914	0.253
1.500	3.096	0.220
1.600	3.278	0.193
1.700	3.460	0.171
1.800	3.641	0.153
1.900	3.823	0.137
2.000	4.005	0.124

ROLL DAMPING COEFFICIENTS

```
   Ship heading  :      120.0 degrees (180 degrees for head seas)
   Ship speed    :       18.0 knots
   Froude number :      0.265

Viscous roll damping based on irregular seaway
   Spectrum                    :      Bretschneider
   Sea state                   :  5
   Significant wave height :      3.250 m
   Characteristic period   :      9.700 seconds

Damping coefficients non-dimensionaled by 2*C44HULL/ROLLNF
(roll damping given as fraction of criteral damping
Roll added mass given as fraction of dry roll inertia
  Roll natural frequency :       0.642 rad/s
  Roll stiffness          :  0.5267E+08 N-m
  Roll inertia (dry)      :  0.9608E+08 N-m**2

Damping components from the following :
  Total       - All roll damping components
  Wave        - Wave radiation damping
  Lift        - Lift forces on skeg, static foils, stabilizing fins, rudders, and bilge keels
  Eddy        - Eddy-making forces on hull, including skeg
  Skin        - Skin friction force on hull
  Visc BK     - Viscous forces on bilge keel
  Visc Foils - Viscous forces on static foils, stabilizing fins, and rudders
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Wave Freq	Enc Freq	Roll Amp	Damping Components Total	Wave	Lift	Eddy	Skin	Visc BK	Visc Foils	Added Mass
0.200	0.219	3.020	0.141	0.014	0.087	0.000	0.000	0.039	0.000	0.310
0.300	0.343	3.020	0.150	0.015	0.087	0.000	0.000	0.047	0.000	0.316
0.400	0.476	3.020	0.159	0.018	0.087	0.000	0.000	0.054	0.000	0.322
0.500	0.618	3.020	0.171	0.024	0.086	0.000	0.001	0.060	0.000	0.329
0.600	0.770	3.020	0.189	0.037	0.086	0.000	0.001	0.066	0.000	0.329
0.700	0.932	3.020	0.212	0.055	0.085	0.000	0.001	0.072	0.000	0.315
0.800	1.102	3.020	0.234	0.071	0.084	0.000	0.001	0.077	0.000	0.290
0.900	1.283	3.020	0.248	0.081	0.083	0.000	0.001	0.082	0.000	0.261
1.000	1.472	3.020	0.252	0.081	0.082	0.001	0.001	0.087	0.000	0.238
1.100	1.672	3.020	0.250	0.075	0.081	0.001	0.001	0.092	0.001	0.225
1.200	1.880	3.020	0.246	0.067	0.080	0.001	0.001	0.096	0.001	0.219
1.300	2.098	3.020	0.242	0.059	0.079	0.001	0.001	0.101	0.001	0.218
1.400	2.326	3.020	0.239	0.052	0.078	0.001	0.001	0.105	0.001	0.219
1.500	2.563	3.020	0.236	0.046	0.077	0.002	0.001	0.110	0.001	0.220
1.600	2.809	3.020	0.234	0.040	0.076	0.002	0.001	0.114	0.002	0.222
1.700	3.065	3.020	0.233	0.035	0.075	0.002	0.001	0.118	0.002	0.224
1.800	3.331	3.020	0.234	0.032	0.074	0.002	0.001	0.123	0.002	0.226
1.900	3.606	3.020	0.234	0.028	0.073	0.003	0.001	0.127	0.002	0.228
2.000	3.890	3.020	0.236	0.026	0.072	0.003	0.001	0.131	0.003	0.230

SHIP LOADS IN REGULAR WAVES

Ship heading : 120.0 degrees (180 degrees for head seas)
Ship speed : 18.0 knots
Froude number : 0.265

Station : 10.000

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Horizontal and vertical shear non-dimensionalized by (0.001 RHO*G*B*L*A)

Torsion, vertical, and horizontal moments non-dimensionalized by (0.001 RHO*G*B*L*L*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave	Hor Shear		Vert Shear		Torsion Mom		Vert Moment		Hor Moment		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.480	-39	0.074	-10	0.017	-105	0.059	57	0.136	-70	0.219	12.373
0.300	0.847	-49	0.347	-3	0.086	-126	0.215	174	0.291	-94	0.343	5.499
0.400	0.897	-54	0.903	7	0.365	-153	1.191	-155	0.445	-138	0.476	3.093
0.500	1.818	-8	2.105	-3	1.110	153	3.231	-158	0.276	92	0.618	1.980
0.600	3.199	-51	4.166	-13	1.268	100	6.848	-160	1.457	-64	0.770	1.375
0.700	3.090	-101	7.543	-26	1.085	73	12.078	-162	3.436	-97	0.932	1.010
0.800	4.618	-156	12.492	-38	0.866	49	18.318	-166	6.047	-111	1.102	0.773
0.900	8.989	177	18.766	-51	0.707	12	22.654	-172	8.856	-116	1.283	0.611
1.000	15.766	168	21.605	-60	0.852	-31	20.269	-172	11.079	-115	1.472	0.495
1.100	24.288	167	22.604	-48	1.183	-53	17.586	-158	11.997	-109	1.672	0.409
1.200	32.708	170	26.959	-37	1.336	-63	13.926	-145	11.243	-98	1.880	0.344
1.300	38.257	177	25.420	-30	1.074	-69	7.744	-123	8.928	-80	2.098	0.293
1.400	38.214	-173	16.949	-8	0.402	-74	4.224	-52	5.793	-52	2.326	0.253
1.500	31.908	-159	14.955	50	0.365	118	5.766	2	3.349	-3	2.563	0.220
1.600	21.676	-141	19.449	87	0.757	118	5.409	33	2.184	63	2.809	0.193
1.700	11.468	-120	20.554	110	0.543	125	3.884	69	1.686	152	3.065	0.171
1.800	4.334	-138	18.423	131	0.153	-123	1.791	102	2.664	-135	3.331	0.153
1.900	6.129	173	14.824	134	0.434	-70	1.081	-100	2.446	-92	3.606	0.137
2.000	6.997	-171	10.833	108	0.232	-64	2.278	-75	1.478	-4	3.890	0.124

SHIP MOTIONS AT CG IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 150.0 degrees (180 degrees for head seas)

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Surge, sway, and heave nondimensionalized by wave amplitude A
Roll, pitch, and yaw nondimensionalized by wave slope KA

Wave	Surge		Sway		Heave		Roll		Pitch		Yaw		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.616	96	0.408	85	0.998	0	0.784	98	0.866	-91	0.363	151	0.233	12.373
0.300	0.530	93	0.351	88	0.988	0	1.093	70	0.870	-95	0.235	161	0.374	5.499
0.400	0.445	92	0.322	92	0.965	0	1.943	19	0.867	-100	0.207	-174	0.531	3.093
0.500	0.357	92	0.256	85	0.910	1	1.976	-71	0.832	-108	0.218	174	0.705	1.980
0.600	0.262	91	0.161	88	0.835	1	0.977	-117	0.746	-120	0.128	176	0.895	1.375
0.700	0.167	90	0.087	93	0.750	-4	0.498	-138	0.588	-139	0.077	-171	1.101	1.010
0.800	0.082	88	0.030	105	0.425	-30	0.212	-153	0.326	-171	0.043	-152	1.324	0.773
0.900	0.021	76	0.004	-120	0.120	33	0.040	-176	0.057	141	0.020	-125	1.563	0.611
1.000	0.010	-60	0.013	-51	0.121	38	0.041	33	0.037	-39	0.008	-74	1.818	0.495
1.100	0.012	-73	0.012	-16	0.033	36	0.043	22	0.026	-63	0.004	2	2.090	0.409
1.200	0.003	-73	0.006	21	0.011	-173	0.014	12	0.004	-86	0.003	77	2.378	0.344
1.300	0.001	122	0.002	171	0.009	-163	0.007	-146	0.003	112	0.002	130	2.683	0.293
1.400	0.002	-109	0.004	-143	0.001	-8	0.006	-156	0.001	92	0.000	-117	3.004	0.253
1.500	0.003	-101	0.001	-120	0.002	13	0.002	47	0.000	-61	0.001	-34	3.341	0.220
1.600	0.001	133	0.002	64	0.001	-154	0.002	32	0.000	-92	0.000	68	3.695	0.193
1.700	0.001	98	0.000	-38	0.000	-131	0.001	-130	0.000	149	0.000	173	4.065	0.171
1.800	0.001	-55	0.001	-89	0.000	50	0.000	-159	0.000	-156	0.000	-8	4.451	0.153
1.900	0.000	-62	0.001	107	0.000	67	0.001	51	0.000	21	0.000	31	4.854	0.137
2.000	0.001	90	0.000	124	0.001	-17	0.000	-178	0.000	40	0.000	-154	5.273	0.124

ADDED RESISTANCE IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 150.0 degrees (180 degrees for head seas)

Added resistance in waves non-dimensionalized by RHO*G*B*B/(L*A*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave Frequency	Added Resistance	Wavelength/ Ship length
0.200	-0.002	12.373
0.300	0.004	5.499
0.400	0.200	3.093
0.500	0.859	1.980
0.600	3.041	1.375
0.700	7.853	1.010
0.800	8.000	0.773
0.900	2.271	0.611
1.000	2.439	0.495
1.100	2.607	0.409
1.200	2.775	0.344
1.300	2.944	0.293
1.400	3.112	0.253
1.500	3.280	0.220
1.600	3.449	0.193
1.700	3.617	0.171
1.800	3.785	0.153
1.900	3.954	0.137
2.000	4.122	0.124

ROLL DAMPING COEFFICIENTS

Ship heading : 150.0 degrees (180 degrees for head seas)
Ship speed : 18.0 knots
Froude number : 0.265

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Damping coefficients non-dimensionaled by 2*C44HULL/ROLLNF
(roll damping given as fraction of criteral damping
Roll added mass given as fraction of dry roll inertia
Roll natural frequency : 0.642 rad/s
Roll stiffness : 0.5267E+08 N-m
Roll inertia (dry) : 0.9608E+08 N-m**2

Damping components from the following :
Total - All roll damping components
Wave - Wave radiation damping
Lift - Lift forces on skeg, static foils, stabilizing fins, rudders, and bilge keels
Eddy - Eddy-making forces on hull, including skeg
Skin - Skin friction force on hull
Visc BK - Viscous forces on bilge keel
Visc Foils - Viscous forces on static foils, stabilizing fins, and rudders

Wave	Enc	Roll	Damping Components							Added
Freq	Freq	Amp	Total	Wave	Lift	Eddy	Skin	Visc BK	Visc Foils	Mass
0.200	0.233	1.487	0.132	0.014	0.087	0.000	0.000	0.030	0.000	0.311
0.300	0.374	1.487	0.139	0.015	0.087	0.000	0.000	0.036	0.000	0.317
0.400	0.531	1.487	0.149	0.020	0.087	0.000	0.000	0.042	0.000	0.325
0.500	0.705	1.487	0.165	0.031	0.086	0.000	0.000	0.047	0.000	0.329
0.600	0.895	1.487	0.188	0.050	0.085	0.000	0.000	0.052	0.000	0.319
0.700	1.101	1.487	0.213	0.071	0.084	0.000	0.001	0.057	0.000	0.290
0.800	1.324	1.487	0.227	0.082	0.083	0.000	0.001	0.062	0.000	0.255
0.900	1.563	1.487	0.228	0.079	0.082	0.000	0.001	0.066	0.000	0.230
1.000	1.818	1.487	0.222	0.070	0.080	0.000	0.001	0.070	0.000	0.220
1.100	2.090	1.487	0.215	0.059	0.079	0.001	0.001	0.075	0.000	0.218
1.200	2.378	1.487	0.209	0.050	0.078	0.001	0.001	0.079	0.001	0.219
1.300	2.683	1.487	0.205	0.043	0.076	0.001	0.001	0.083	0.001	0.221
1.400	3.004	1.487	0.201	0.036	0.075	0.001	0.001	0.087	0.001	0.224
1.500	3.341	1.487	0.199	0.031	0.074	0.001	0.001	0.091	0.001	0.226
1.600	3.695	1.487	0.199	0.028	0.073	0.001	0.001	0.095	0.001	0.229
1.700	4.065	1.487	0.199	0.025	0.072	0.002	0.001	0.099	0.001	0.231
1.800	4.451	1.487	0.202	0.024	0.071	0.002	0.001	0.103	0.002	0.232
1.900	4.854	1.487	0.203	0.021	0.070	0.002	0.001	0.107	0.002	0.232
2.000	5.273	1.487	0.197	0.013	0.069	0.002	0.001	0.110	0.002	0.233

SHIP LOADS IN REGULAR WAVES

Ship heading : 150.0 degrees (180 degrees for head seas)
Ship speed : 18.0 knots
Froude number : 0.265

Station : 10.000

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Horizontal and vertical shear non-dimensionalized by (0.001 RHO*G*B*L*A)

Torsion, vertical, and horizontal moments non-dimensionalized by (0.001 RHO*G*B*L*L*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave	Hor Shear		Vert Shear		Torsion Mom		Vert Moment		Hor Moment		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.416	-36	0.244	-15	0.011	-110	0.160	156	0.086	-61	0.233	12.373
0.300	0.701	-46	1.013	-10	0.072	-134	1.184	-165	0.181	-101	0.374	5.499
0.400	0.653	-31	2.999	-21	0.383	-172	4.238	-161	0.312	-173	0.531	3.093
0.500	1.779	-35	7.637	-34	0.780	109	10.095	-163	0.587	-55	0.705	1.980
0.600	1.323	-120	16.575	-46	0.573	62	18.593	-165	2.283	-102	0.895	1.375
0.700	4.047	169	30.371	-57	0.406	13	27.022	-169	4.250	-114	1.101	1.010
0.800	9.219	157	45.056	-64	0.512	-41	28.705	-173	5.702	-115	1.324	0.773
0.900	15.200	159	53.585	-63	0.682	-64	21.747	-167	5.688	-107	1.563	0.611
1.000	19.591	168	57.270	-62	0.551	-71	11.545	-160	4.190	-86	1.818	0.495
1.100	19.819	-178	39.209	-68	0.074	-65	1.629	-30	2.359	-44	2.090	0.409
1.200	15.788	-160	6.846	-78	0.372	102	6.602	6	1.093	18	2.378	0.344
1.300	10.798	-150	12.978	99	0.310	100	2.779	8	0.668	-170	2.683	0.293
1.400	10.066	-167	10.413	91	0.126	-50	2.035	-172	1.773	-120	3.004	0.253
1.500	12.520	-169	3.359	93	0.214	-62	1.155	-164	0.762	-58	3.341	0.220
1.600	9.641	-148	6.534	120	0.118	126	1.178	19	1.285	60	3.695	0.193
1.700	5.630	-124	11.006	122	0.121	125	0.540	52	0.312	-105	4.065	0.171
1.800	7.921	-152	10.663	133	0.160	-51	0.366	-102	1.413	-79	4.451	0.153
1.900	8.539	-139	11.480	115	0.101	129	0.754	-101	1.097	94	4.854	0.137
2.000	2.429	-84	14.171	103	0.217	-142	2.634	-167	0.676	173	5.273	0.124

SHIP MOTIONS AT CG IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 180.0 degrees (180 degrees for head seas)

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Surge, sway, and heave nondimensionalized by wave amplitude A
Roll, pitch, and yaw nondimensionalized by wave slope KA

Wave	Surge		Sway		Heave		Roll		Pitch		Yaw		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.681	95	0.000	85	0.997	0	0.000	100	0.999	-92	0.000	151	0.238	12.373
0.300	0.572	93	0.000	88	0.983	0	0.000	71	1.003	-96	0.000	162	0.385	5.499
0.400	0.466	92	0.000	93	0.945	0	0.000	15	0.989	-102	0.000	-169	0.551	3.093
0.500	0.355	92	0.000	83	0.869	1	0.000	-93	0.925	-111	0.000	170	0.736	1.980
0.600	0.241	91	0.000	89	0.768	2	0.000	-132	0.785	-126	0.000	179	0.940	1.375
0.700	0.132	90	0.000	96	0.623	-7	0.000	-150	0.542	-149	0.000	-162	1.163	1.010
0.800	0.046	84	0.000	120	0.171	-17	0.000	-165	0.194	168	0.000	-137	1.405	0.773
0.900	0.007	-27	0.000	-60	0.162	45	0.000	40	0.032	-7	0.000	-93	1.665	0.611
1.000	0.014	-72	0.000	-23	0.065	32	0.000	20	0.043	-57	0.000	-19	1.945	0.495
1.100	0.005	-73	0.000	12	0.007	-175	0.000	11	0.011	-85	0.000	66	2.243	0.409
1.200	0.001	117	0.000	163	0.012	-167	0.000	-144	0.004	120	0.000	123	2.561	0.344
1.300	0.002	-110	0.000	-145	0.001	34	0.000	-160	0.002	83	0.000	-124	2.897	0.293
1.400	0.003	-102	0.000	-134	0.002	2	0.000	48	0.001	-60	0.000	-34	3.252	0.253
1.500	0.001	122	0.000	64	0.001	-144	0.000	28	0.000	-123	0.000	138	3.626	0.220
1.600	0.001	90	0.000	-74	0.000	171	0.000	-131	0.000	129	0.000	176	4.019	0.193
1.700	0.001	-64	0.000	-99	0.000	23	0.000	77	0.000	-27	0.000	9	4.431	0.171
1.800	0.000	104	0.000	115	0.000	-81	0.000	99	0.000	-5	0.000	103	4.862	0.153
1.900	0.000	21	0.000	-54	0.001	-20	0.000	-71	0.000	-38	0.000	-131	5.311	0.137
2.000	0.001	-67	0.000	19	0.003	154	0.000	-12	0.001	172	0.000	33	5.780	0.124

ADDED RESISTANCE IN REGULAR WAVES

Ship speed : 18.0 knots
Froude number : 0.265
Ship heading : 180.0 degrees (180 degrees for head seas)

Added resistance in waves non-dimensionalized by RHO*G*B*B/(L*A*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave Frequency	Added Resistance	Wavelength/ Ship length
0.200	0.000	12.373
0.300	0.011	5.499
0.400	0.203	3.093
0.500	1.370	1.980
0.600	5.005	1.375
0.700	9.394	1.010
0.800	5.359	0.773
0.900	5.762	0.611
1.000	6.166	0.495
1.100	6.569	0.409
1.200	6.972	0.344
1.300	7.375	0.293
1.400	7.779	0.253
1.500	8.182	0.220
1.600	8.585	0.193
1.700	8.988	0.171
1.800	9.391	0.153
1.900	9.795	0.137
2.000	10.198	0.124

ROLL DAMPING COEFFICIENTS

```
   Ship heading  :      180.0 degrees (180 degrees for head seas)
   Ship speed    :       18.0 knots
   Froude number :      0.265

Viscous roll damping based on irregular seaway
   Spectrum                 :      Bretschneider
   Sea state                :  5
   Significant wave height  :     3.250 m
   Characteristic period    :     9.700 seconds

Damping coefficients non-dimensionaled by 2*C44HULL/ROLLNF
(roll damping given as fraction of criteral damping
Roll added mass given as fraction of dry roll inertia
  Roll natural frequency :       0.642 rad/s
  Roll stiffness         :  0.5267E+08 N-m
  Roll inertia (dry)     :  0.9608E+08 N-m**2

Damping components from the following :
  Total      - All roll damping components
  Wave       - Wave radiation damping
  Lift       - Lift forces on skeg, static foils, stabilizing fins, rudders, and bilge keels
  Eddy       - Eddy-making forces on hull, including skeg
  Skin       - Skin friction force on hull
  Visc BK    - Viscous forces on bilge keel
  Visc Foils - Viscous forces on static foils, stabilizing fins, and rudders
```

Wave Freq	Enc Freq	Roll Amp	Damping Components							Added Mass
			Total	Wave	Lift	Eddy	Skin	Visc BK	Visc Foils	
0.200	0.238	0.000	0.102	0.014	0.087	0.000	0.000	0.000	0.000	0.311
0.300	0.385	0.000	0.102	0.015	0.087	0.000	0.000	0.000	0.000	0.318
0.400	0.551	0.000	0.107	0.021	0.087	0.000	0.000	0.000	0.000	0.327
0.500	0.736	0.000	0.120	0.034	0.086	0.000	0.000	0.000	0.000	0.329
0.600	0.940	0.000	0.141	0.056	0.085	0.000	0.000	0.000	0.000	0.314
0.700	1.163	0.000	0.160	0.077	0.084	0.000	0.000	0.000	0.000	0.279
0.800	1.405	0.000	0.165	0.083	0.083	0.000	0.000	0.000	0.000	0.243
0.900	1.665	0.000	0.157	0.075	0.081	0.000	0.000	0.000	0.000	0.225
1.000	1.945	0.000	0.144	0.065	0.080	0.000	0.000	0.000	0.000	0.218
1.100	2.243	0.000	0.133	0.054	0.078	0.000	0.000	0.000	0.000	0.218
1.200	2.561	0.000	0.123	0.046	0.077	0.000	0.000	0.000	0.000	0.220
1.300	2.897	0.000	0.114	0.038	0.076	0.000	0.000	0.000	0.000	0.223
1.400	3.252	0.000	0.107	0.033	0.074	0.000	0.000	0.000	0.000	0.226
1.500	3.626	0.000	0.101	0.028	0.073	0.000	0.000	0.000	0.000	0.228
1.600	4.019	0.000	0.097	0.025	0.072	0.000	0.000	0.000	0.000	0.231
1.700	4.431	0.000	0.095	0.024	0.071	0.000	0.000	0.000	0.000	0.232
1.800	4.862	0.000	0.092	0.021	0.070	0.000	0.000	0.000	0.000	0.232
1.900	5.311	0.000	0.081	0.012	0.069	0.000	0.000	0.000	0.000	0.234
2.000	5.780	0.000	0.076	0.007	0.069	0.000	0.000	0.000	0.000	0.235

SHIP LOADS IN REGULAR WAVES

Ship heading : 180.0 degrees (180 degrees for head seas)
Ship speed : 18.0 knots
Froude number : 0.265

Station : 10.000

Viscous roll damping based on irregular seaway
Spectrum : Bretschneider
Sea state : 5
Significant wave height : 3.250 m
Characteristic period : 9.700 seconds

Horizontal and vertical shear non-dimensionalized by (0.001 RHO*G*B*L*A)

Torsion, vertical, and horizontal moments non-dimensionalized by (0.001 RHO*G*B*L*L*A)

where RHO = Water density
G = gravitational acceleration
B = ship beam
L = ship length
A = wave amplitude

Wave	Hor Shear		Vert Shear		Torsion Mom		Vert Moment		Hor Moment		Enc	Wavelen/
Freq	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Amp	Phase	Freq	Ship len
0.200	0.000	-36	0.325	-16	0.000	-107	0.243	164	0.000	-59	0.238	12.373
0.300	0.000	-47	1.354	-13	0.000	-130	1.683	-164	0.000	-106	0.385	5.499
0.400	0.000	-16	4.206	-27	0.000	-171	5.705	-162	0.000	169	0.551	3.093
0.500	0.000	-48	10.920	-40	0.000	90	13.148	-164	0.000	-65	0.736	1.980
0.600	0.000	-161	23.732	-52	0.000	43	22.940	-167	0.000	-107	0.940	1.375
0.700	0.000	158	41.701	-62	0.000	-16	30.319	-171	0.000	-115	1.163	1.010
0.800	0.000	155	56.806	-67	0.000	-57	26.762	-173	0.000	-112	1.405	0.773
0.900	0.001	162	64.644	-65	0.000	-70	16.930	-166	0.000	-96	1.665	0.611
1.000	0.001	176	55.129	-70	0.000	-72	2.830	-156	0.000	-57	1.945	0.495
1.100	0.001	-165	20.634	-82	0.000	99	6.269	3	0.000	4	2.243	0.409
1.200	0.000	-152	7.104	97	0.000	97	3.456	-4	0.000	-179	2.561	0.344
1.300	0.000	-167	7.594	63	0.000	-37	2.447	-166	0.000	-123	2.897	0.293
1.400	0.000	-169	3.497	-47	0.000	-59	1.340	172	0.000	-54	3.252	0.253
1.500	0.000	-147	3.660	150	0.000	123	1.579	21	0.000	62	3.626	0.220
1.600	0.000	-133	9.269	119	0.000	113	0.221	-73	0.000	-91	4.019	0.193
1.700	0.000	-151	7.245	125	0.000	-43	0.689	-135	0.000	-75	4.431	0.171
1.800	0.000	-132	10.143	117	0.000	140	0.521	-172	0.000	110	4.862	0.153
1.900	0.000	-130	7.208	114	0.000	-117	3.959	-179	0.000	-95	5.311	0.137
2.000	0.001	-138	46.592	169	0.000	20	8.910	-41	0.000	62	5.780	0.124

***** RMS VALUES IN UNIDIRECTIONAL SEAS *****

Ship speed : 18.000 knots
Froude number : 0.265

Sea state : 5
Spectrum : Bretschneider
Significant wave height : 3.250 m
Characteristic wave period : 9.700 seconds

Heading is sea direction (to) relative to ship speed
Heading of 180 degrees for head seas

Motions at Ship CG

RMS Displacements and Zero-crossing Periods

Heading	Surge	Tz	Sway	Tz	Heave	Tz	Roll	Tz	Pitch	Tz	Yaw	Tz
deg	m	s	m	s	m	s	deg	s	deg	s	deg	s
0.0	2.01	26.7	0.00	0.0	0.23	24.1	0.00	0.0	0.64	24.2	0.00	0.0
30.0	1.46	21.6	0.68	28.1	0.28	21.0	1.64	21.7	0.63	20.7	1.66	23.2
60.0	0.62	13.5	0.56	14.0	0.47	14.2	3.85	12.7	0.73	13.2	1.32	12.9
90.0	0.00	5.3	0.63	8.5	0.82	7.7	3.27	8.7	0.05	4.5	0.11	7.2
120.0	0.16	7.2	0.29	7.6	0.69	6.6	2.43	7.1	0.99	5.9	0.35	6.3
150.0	0.15	7.0	0.09	7.4	0.49	6.4	1.18	6.8	0.99	6.0	0.16	6.3
180.0	0.13	6.9	0.00	7.2	0.43	6.3	0.00	6.9	0.93	6.0	0.00	6.2

Added Resistance in Irregular Waves

Heading	RMS Added resistance
(deg)	N
0.0	13641.213
30.0	29362.689
60.0	53402.039
90.0	22918.477
120.0	69583.578
150.0	104383.828
180.0	143468.094

Seekeeping at Position on Ship

Label : BRIDGE   Station = 3.00   Y = 0.000 m   Z = 6.720 m (wrt to CG)

Motions at station

Heading	*********Vertical***************				********Lateral*********			*****Longitudinal*****		
	Disp	Tz	Vel	Acc	Disp	Tz	Acc	Disp	Tz	Acc
deg	m	s	m/s	g	m	s	g	m	s	g
0.0	0.61	24.4	0.16	0.007	0.00	0.0	0.000	1.94	26.7	0.011
30.0	0.64	20.8	0.19	0.007	1.04	23.1	0.008	1.39	21.6	0.012
60.0	0.83	13.5	0.39	0.019	0.68	13.3	0.016	0.54	13.5	0.012
90.0	0.84	7.5	0.70	0.068	0.79	7.8	0.059	0.01	4.5	0.001
120.0	1.24	6.1	1.28	0.147	0.60	7.5	0.047	0.11	6.2	0.014
150.0	1.15	6.0	1.19	0.134	0.23	7.5	0.018	0.11	6.1	0.013
180.0	1.07	6.0	1.11	0.125	0.00	7.5	0.000	0.10	6.0	0.013

Forces relative to local axes and motion-induced interruptions

Lat tip coeff = 0.250 , Long tip coeff = 0.170 , Time for operation = 60.0 s

Heading	***Lateral***		**Longitudinal**		Total
	LFE	MII	LFE	MII	MII
deg	g		g		
0.0	0.000	0.000	0.004	0.000	0.000
30.0	0.029	0.000	0.004	0.000	0.000
60.0	0.065	0.006	0.007	0.000	0.006
90.0	0.102	1.031	0.002	0.000	1.031
120.0	0.082	0.435	0.025	0.032	0.467
150.0	0.035	0.001	0.025	0.020	0.021
180.0	0.000	0.000	0.024	0.009	0.009

Slamming and Deck Wetness Calculations

	Zero speed	At speed
Draft	5.072 m	5.244 m
Freeboard	7.068 m	6.896 m

Heading	****Vertical****		Deck wetness		Keel emergence		Max slam pres		Max slam force	
	Rel disp	Rel vel	Prob	Rate/hr	Prob	Rate/hr	Expected	Extreme	Expected	Extreme
deg	m	m/s					kPa	kPa	N /m	N /m
0.0	0.84	0.24	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
30.0	0.75	0.22	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
60.0	0.68	0.34	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
90.0	0.23	0.33	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
120.0	1.13	1.51	0.0000	0.0	0.0000	0.0	0.00	0.00	0.0	0.0
150.0	1.33	1.83	0.0000	0.0	0.0004	0.3	24.81	83.83	15795.0	53363.4
180.0	1.34	1.89	0.0000	0.0	0.0005	0.4	27.33	90.00	17396.1	57291.3

RMS Sea Loads at Station 10.0

Units for shears : kN
Units for bending moments and torsion : kN-m

Heading	Hor shear		Vert shear		Torsion		Vert bend		Hor bend	
deg	RMS	Tz	RMS	Tz	RMS	Tz	RMS	Tz	RMS	Tz
0.0	0.0	0.0	461.2	19.6	0.0	0.0	31336.4	26.5	0.0	0.0
30.0	218.1	29.5	455.9	20.7	802.6	21.7	29486.8	21.8	8879.6	23.8
60.0	206.3	12.5	692.9	12.5	2117.6	12.4	31159.9	12.3	12546.4	12.3
90.0	19.1	7.3	62.9	4.4	2304.4	7.1	3715.1	4.5	4059.4	4.8
120.0	194.3	3.2	206.0	3.8	1932.9	5.5	26538.7	4.9	11700.8	4.2
150.0	152.7	3.3	519.9	4.1	980.4	4.9	38587.8	5.1	7276.5	4.5
180.0	0.0	3.2	618.4	4.1	0.0	4.9	40288.4	5.1	0.2	4.6

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SHIPMO7 is an updated strip theory program for computing ship motions and sea loads in regular and irregular seas. SHIPMO7 includes appendage forces and viscous forces when evaluating motions and sea loads in the lateral plane. The revised program also introduces a boundary element method which eliminates irregular frequencies from computed hydrodynamic coefficients. The SHIPMO input format has been revised to improve consistency and clarity. The revised output includes improvements to aid checking of input data for ship appendages. In addition to computing ship motions and sea loads, SHIPMO7 also gives derived responses, including local accelerations, slamming, deck wetness, motion-induced interruptions, and added resistance in waves.

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